SMOKE ABATEMENT LEAGUE OF
GREAT BRITAIN

The Smoke Inspector
and the
Cost of Production

by

H. G. CLINCH, M.R.San.I., M.I.H.,
Chief Smoke Inspector, Halifax

SIXTH SESSION
of the
Conference on Smoke Abatement
in the
Lord Mayor's Parlour, Town Hall, Manchester
November 4th, 5th and 6th, 1924

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Is the Smoke Inspector a Nuisance ?

By a nuisance, I mean, is he an incubus on the community at large, a source of distraction and worry to the manufacturing world, waiting with wary eye for whom he may entrap into the net of the law, and is he a reasonable business risk ? Or again, is he of incalculable value in promoting the health of the community, and at the same time compelling efficiency in the management of steam boilers ?

In submitting this paper to the Conference of the Smoke Abatement League, my object is to give a lead to a discussion by recognised authorities, on the whole question of the need for an efficient smoke inspection service throughout industrial Britain.

When any great social reform is advocated, two questions invariably are asked :—

1. What will it cost ?
2. Is it worth while ?

No intelligent person will nowadays dispute the necessity of reform in the " Sanitation of the Air," in fact, there are signs of a quickening in the interest of the public on this question. The proverbial man in the street is beginning to ask why he should enjoy the benefits of bright sunlight and clean air during his annual holidays only, and for the rest of the year live in a state of perpetual gloom and choke his lungs with filth.

His wife, also, is beginning to awake to the fact, that she is doomed to a life consisting mostly of a long and hopeless struggle against dirt, mainly in the form of soot manufactured at great expense. She is at last beginning to realise the reason of her enormous washing costs, with the consequent increased wear of fabrics involved, and I am confident that she will soon ask why she should be robbed of her hours of leisure, and her home of its brightness, by unnecessary smoke.

The greatest mystery of my life has been the indifference of the people to the question of clean air. An offensive smell, the presence of dirt in the public water supply, or a dirty tram-car, can always be relied on to raise a storm of protests from would-be reformers who will cry shame on those who misspend public funds derived from the rates. Yet, an atmosphere loaded with dirty, greasy, acid-impregnated solids and vapours, is regarded as a normal state of affairs. In fact, it is no exaggeration to say that, in some districts, it is regarded as an indication of good trade and prosperity. This can only be due to the fact that, speaking generally, the public are ignorant of the evils they suffer, and needlessly suffer, through a smoke-laden atmosphere. I refuse to believe that the people will remain indifferent and silent when they realise that smoke robs them of probably as much as ten years of life, that it exerts a dulling influence on their whole existence, depriving them of the enjoyment of their full vigour, setting up a predisposition to considerable physical and mental suffering, in addition to economic loss through the influence of such abnormalities as depression, fatigue, bronchitis, tubercular disease, and rickets.

To what extent is the smoke inspector able to influence matters ?

At present, the activities of the smoke inspector are confined by law to the black smoke produced by arrested combustion in the furnace of the steam boiler, and opinions differ as to the exact proportion of the total air pollution caused by this particular type of smoke. I cannot agree that the " black" smoke, which is such an alarming factor in the obstruction of sunlight, is

emitted by any other than the factory chimney ; the low temperature smoke of the domestic fire is not black, it consists mostly of blue, yellow or even green vapours, a fact which is obvious to any observer. This is emphasised also by the figures of estimated soot deposits issued by the Advisory Committee on Atmospheric Pollution, in which we notice that in London, in spite of the tremendous area and mass effect of the domestic chimney, the soot deposits are at the comparatively low level of about 250 tons per square mile, whereas in our northern towns the figure rises to from 450 to 650 tons. Surely then, we have no further need to search for the cause of the characteristic gloom of the manufacturing towns of Lancashire, Yorkshire and the Midlands, nor need we wonder why nearly 25 per cent. of the population of those towns succumb to " chest troubles."

To what extent, then, is it possible to abolish this " Black Death " ?

Eminent engineers of to-day are repeatedly telling us that the steam boiler can be efficiently worked so as to produce little or no smoke. Government Commissions appointed during the last hundred years have also agreed on this point. I have no hesitation in saying that the manufacture of black smoke in the boiler furnace is very bad business for those who foot the fuel bill.

Why then, it may be asked, is there any need for smoke inspectors ?

Must it be admitted that, although we are recognised to be, as a nation, the " World's Best Engineers," our manufacturers need the interference of public officials and the spur of the law, in order to induce them to conduct the steam-generating part of their business with efficiency ? In large numbers of cases this undoubtedly is a fact, and it is to our shame that it should be so.

Why is this the case ?

A very careful study of the whole question has convinced me that the average manufacturer is so fully occupied with the technique of his business, and the buying and selling necessarily

involved, that he has no time at his disposal for a study of the boiler plant, and is obliged to leave that aspect to others, in some cases being very badly served.

During recent years, I have watched with keen interest the sequence of events following the merging of large numbers of private firms into giant combines, particularly in industries necessitating a constantly varying load on the boilers. The small private firms were content to carry on their wasteful, death-dealing methods to the last, but the combine at once employed the services of highly competent chemist engineers ; and what a transformation followed ! I have seen chimney after chimney cleaned up, not in the interests of public health and the fear of the law, but solely as a result of the adoption of efficient methods. I have for long maintained that the annual inspection of the power plant by a competent engineer would be good business to any manufacturer.

At the present time, the work of the smoke inspector is rendered difficult by the apathy of the public, as reflected in the decisions of magistrates, and also by the total inadequacy of existing legal power. This has led me to adopt the method of giving all the advice and assistance which lie in my power to those concerned ; and by carefully explaining faults and suggesting improvements, I have produced results which have been even more astonishing to me than to the people who have reaped the benefit, and I may state, with all due modesty, that by this means I have produced a result which is already noticeable to " the man in the street," in fact, three years of this method have achieved far more than thirty years of the old ineffective reliance upon legal methods only.

It is my claim that an efficient smoke inspector, given a free hand, can contribute considerably to economy in the cost of production :—

1. By reducing fuel costs.
2. By reducing the obstruction to sunlight, thereby increasing the mental and physical vigour of the whole population, resulting in more rapid and efficient production throughout.

3. By reducing the present terrible economic loss of sickness.

It is no idle boast to say that all this can be achieved for a town, a county, or a country, at a cost of a penny per head of population per annum.

PROCESS SMOKE.

The black smoke from the boiler does not, by any means, constitute the whole of the problem ; we still have the unavoidable smoke of process work to contend with.

The legislature have always been most careful to provide adequate exemptions for smoke of this description, and, I believe, wrongly so. It must be admitted that, in the present state of knowledge, the production of smoke is unavoidable in the course of certain manufactures, but I fail to see any good reason why this should be discharged to atmosphere with its solids unconsumed. Do we allow crude sewage, or poisonous dyes, to pollute our rivers just because the purification process is not a paying proposition ? Why, then, should we load our air with death-dealing soot ? I venture to say that if smoke were accompanied by an offensive odour, our forefathers would not have left us such a vile legacy.

I am fully aware of the fact that careful consideration in some cases would have to be given to the question of precautions against explosion ; but admitting this, and certain engineering difficulties, I see no reason why all process smoke should not be raised to ignition, supplied with air, and consumed in special boilers or furnaces, and so discharged to atmosphere as invisible gases instead of as solid carbon in suspension. The comparatively trifling cost of running such smoke-burning installations could be reckoned as the price of the increased health and energy of the employees of all classes, and I have no doubt that, indirectly, it would be a paying proposition, although this naturally would be a very difficult matter to prove.

In conclusion, I submit for discussion my opinion that the expenditure of a penny per annum per head of population on

an efficient smoke inspection service throughout industrial Britain would, by reducing fuel costs, and increasing the supply of energy-giving and germ-killing sunlight to the active population, lead to a much-needed decrease in the cost of production. Further, that it would be a gilt-edged investment for the nation in that the export trade would be stimulated, and that, under brighter skies, there would be far less irritation and dissatisfaction in the relations between capital and labour. In fact, I suggest a brighter and more cheerful atmosphere as of the greatest importance in the promotion of good feeling and as one of the cures for strikes.

The municipality would benefit by the reduction of the need for expensive sanatoria, and in reduced cleansing costs, whilst the individual would derive untold benefits by reduction of his household upkeep and lighting, and his sickness costs.

I would suggest a " Clean Sky " as a substitute for Acts of Parliament which give a return of 9d. for 4d.

Surely, if it is possible to abolish the wicked gloom of to-day, and by so doing to show an immense financial saving on balance, it is criminal to remain passive and indifferent. Would that we could foresee the comments of the generations to come on the sins of ommision perpetrated by " We of the Dark and Gloomy Age " !

J. F. Tangye, Printer, Manchester.

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SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN

The Law Against Smoke

by

JOHN W. GRAHAM, M.A.
Chairman of the Smoke Abatement League of Great Britain

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THE PRESENT LAW.

BY the Public Health Act of 1875, manufacturing smoke may be treated under one of two clauses, one which definitely forbids smoke which can be proved to be black, as a nuisance, and another which without limitation of colour, declares that every owner or fireman is to avoid smoke *as far as practicable.* This latter clause has been found to be unworkable in practice, and is never used; for it leads to a dispute as to what is "practicable," in which expensive expert testimony is likely to be brought in. The London County Council vainly prosecuted the Lots Road Electric Station, and were cast in heavy costs of £300 because the magistrate declared that the smoke was proved to be grey.

Moreover, Section 334 says: "Nothing in this Act shall be construed to extend to mines of different descriptions, so as to interfere with or to obstruct the efficient working of the same; nor to the smelting of ores or minerals, nor to the calcining, puddling and rolling of iron and other metals, nor to the conversion of pig iron into wrought iron, so as to obstruct or interfere with any of such processes respectively."

The last words show that the exemption for smoke in those processes does not extend beyond the necessities of the process. But it is extraordinarily difficult for an observer to know exactly how much is necessary.

In practice our smoke legislation is a dead letter, except in London and about seven provincial towns, Manchester, Glasgow, Sheffield, Bradford and Liverpool, and the two towns of Leicester and Nottingham where lace and hosiery have to be kept clean. There may be a few other places of which I have not heard. The fines are extremely low and usually run to about 30s. or £2, though it is possible to go higher, and a Sheffield firm was fined £34 lately. The health committees and magistrates are often connected with the offenders socially or by family ties. "Well, we have to live with them," a magistrate said to me the other day.

In my opinion it is impossible to legislate against domestic smoke at present. It is not possible to make gas or electricity compulsory and universal yet. Any legislation against the smoke from the kitchen fire would have to allow at least ten minutes' smoke in the half-hour; and the quantity is so small from each chimney that there would be much disputing over it. The time is, however, close upon us when the result of the many processes of low temperature carbonisation will be universally accessible. When that has become established, legislation against all use of raw coal may become practicable and reasonable; at any rate, legislation against domestic smoke will be in order.

RECENT HISTORY OF THE MOVEMENT.

In 1909, at a Smoke Conference collected at Sheffield, which met in the Town Hall, the Smoke Abatement League of Great Britain was founded, and produced a memorial which was presented to Mr. John Burns, at the Local Government Board, by 28 members of Parliament and members of corporations. It was plain that the permanent officials were unsympathetic, not wanting more work put upon them. The Local Government Board had previously refused us a conference with them. The memorial embodied the proposals which I will describe later on. Nineteen considerable municipalities, led by Glasgow, Liverpool and Manchester, signed the memorial. Nothing came of it at the time, except leading articles in several papers. The Ministry of Health, formerly the Local Government Board, has been a disappointment always.

Our next task was to draft a Bill. I spent a year over this, and communicated with 82 of the principal municipalities in the country, sending round to them successive drafts for criticism. We finally reached an agreed scheme, which may fairly be called "The Municipalities Bill." We obtained the approval of the London Coal Smoke Abatement Society, and Mr. Gordon Harvey attempted to have it introduced into the House of Commons as a private measure. A year passed without result; and finally Lord Newton offered his help in the House of Lords, where the Bill was read a first time in the Spring of 1914. It had been changed slightly in wording by that time from the first draft of 1912. Copies are in the room. The Government, thinking that something unofficial or unwise might be done, asked Lord Newton to withdraw the Bill, promising to appoint a Departmental Committee to look into the whole subject. As the prospects of the Bill as a private measure were poor, he and the League agreed to this. A Departmental Committee was appointed and had a number of sittings under Mr. Rea, until it was adjourned *sine die* on the outbreak of war in August, 1914. With some difficulty it was resuscitated in 1920 under Lord Newton, saw a great many more witnesses, visited provincial centres, and issued an interim and, at the end of 1921, a final Report. The minutes of evidence are not published. It recommended the increase of fines, the standardising of the time allowed for making smoke, the provision of a central Department on the subject at the Ministry of Health, and an increase of the size of the areas dealing with the subject. These were all valuable and necessary proposals, but the Committee was so impressed by the manufacturers' statements from Sheffield and the Potteries, to the effect that smoke-making was essential to their business, that they gave way upon the crucial point of making smoke emission a definite offence, and recommended that the words "as far as practicable" should occur in the Act; the onus of proving what was practicable being laid on the manufacturer.

But the effect of this is to carry the difficulty special to these two trades into the whole smoke-making of the country, and to raise the question of what is practicable, over every smoky

boiler. The whole country must be dirty that Sheffield and the Potteries may go on as they are.

In lieu of the exemption clause, Section 334, there should be given an opportunity to any manufacturers asserting that smoke is necessary to their business, to appear before a Government expert Commission, which would be empowered to use the principle of the words " as far as practicable," and permit smoke for some processes for a specified number of years, say, two or three, awaiting improvement in technical methods in the future. The defence, " as far as practicable," should be carefully omitted from every other place in the Bill, and the sentence about taking into account the element of cost in abating smoke should be omitted. No doubt that would be taken into account very seriously by any Bench of which we have hitherto had any experience ; I think it not necessary to weight a public authority with this handicap under the Act. There is, in fact, hardly any capital expenditure on smokeless apparatus which does not in time amply repay the outlay if it succeeds.

The late Coalition and Conservative Governments have introduced two Bills in two successive years into the House of Lords, neither of which has been carried through. One can only be glad of their failure. They were compiled after consultation with the representatives of trade interests, and their result might be said to be smoke promotion rather than smoke prevention. They were " legislation by reference " to past Acts, amending the Act of 1875 (for London, the 1891 Act) in various ways, and were severely criticised in the House of Lords in this sense. They actually extended the businesses that were exempted in Section 334, so as to include every process in the iron and steel trades. They avoided the appointing of any extra staff at the Board of Health as a Central Smoke Authority ; they extended the smoke areas to those of the County Councils and County Borough Councils ; they satisfactorily increased the fines ; and they made the plea that smoke was abolished " as far as practicable," " having regard to the cost involved " in abolishing it—a " defence in every case." This alone would discourage any

Health Committee from prosecuting. Under these Governments there was no real intention effectually to clean the air which the people breathe. The Department shuns more work, the Treasury bars expenditure, and trade interests, whose representatives unfortunately take a short view, commanded many votes in the House of Commons.

The Labour Government introduced a third Bill in 1924. To our intense disappointment it was a small Bill on the lines of the other two, a departmental Bill. It contained however one improvement. Black smoke from boilers remains amenable to the present law. Smoke not black may offer the defence that what is " practicable " is being done. Thus, though reactionary, it is not as reactionary as the others. It is to be hoped that it will fall with the Parliament. The only reason for the Bill being made ineffective with smoke not black, that I can think of, is that this brown or yellow smoke comes from ironworks, which are apparently to be protected at every corner.

We did our best to obtain at this Conference an up-to-date statement from the Potteries ; but my letters did not even receive an answer. This is regrettable ; but the situation there is that there is a continuous extension of the use of gas firing, somewhat cautiously and experimentally, and that most potters are not yet convinced that it is of universal application. They refer to difficulties with Staffordshire blue bricks and with bone china. But Mr. Marlow, of Messrs. Minton, Hollins & Co., claimed four years ago that he could and did make then every kind of pottery in a tunnel continuous gas furnace. The furnaces which have to be heated up and cooled every time are plainly extravagant, and must for economy's sake give place to a continuous furnace, which the ware passes slowly through from one end to the other, and which is never cooled. I do not know whether the Stoke Corporation yet supplies Mond or producer gas on a large scale. It would be a great help. The manufacturers there maintain a Research Institute, and the whole situation is not without hope. But a reasonable Government stimulus to research and to progress would be a great benefit and no hardship to anyone.

Up to 1921, at any rate, smoke prosecutions were unheard of in the Potteries ; probably they are still.

From Sheffield also we made several attempts to obtain a paper giving in a careful and reasonable way the Sheffield situation ; we asked an expert to state their case, and any improvements we may hope for, but, ultimately they declined to discuss it with us. I am sorry for this, for in our controversies with their spokesman in the past we have not been much illuminated. Heat rather than light was the form of energy evolved. (Reheating is one of the industries of Sheffield.)

They say that in the rolling, puddling and reheating furnaces, particularly in the manufacture of high carbon steel, a smoky flame in the furnace itself is necessary to prevent the oxidising of the metal ; that is, very heavy smoke has to be emitted for about 12 hours, followed by rather less for another twelve ; and some afterwards. Clearly this is a case which demands treatment separately from that of the rest of the country, which merely sends its smoke shamefacedly up the chimney. As knowledge and opinion stand at present, I believe they would get from an expert Commission, such as we propose, their high steel exemption for a time. I cannot imagine any Government body which would at present seriously interfere with them. But they make, I am told by a local observer, about seven times as much smoke as they need, under cover of this exemption. If we could get rid of this, Sheffield would be a different place to live in.

Moreover, slack manufacturers, or men who will not disturb their routine, or invest capital to avoid public damage, will have to meet in such an enquiry the criticisms one hears. Furnaces have been in use at two places near Glasgow, at one in Manchester, and one in Germany, for which it is claimed that they have or had the required reducing atmosphere without smoke. And the question of a smoky gas flame is constantly brought up. These are highly technical matters on which I claim no personal authority; but it is surely desirable that a technical inquiry should be held, not before a bewildered magistrate, nor in a public meeting, but among those who know.

Then we may reach justice for the people as well as the manufacturers of the steel towns. The district from Sheffield along the Midland line to the north is the most horrible place in England, unfit for human habitation ; but I notice that amongst their disgusting smoke stacks the manufacturers are not ashamed to put their names on their works. They live far away themselves.

OUTLINE OF REFORM.

It would be better to have a new Act rather than a series of complicated amendments to the Act of 1875 (for London, the Act of 1891). The word " black " should be omitted. The principal clause in our Bill of 1914 is not quite satisfactory. It would be simpler and safer if it ran thus :—

> " If any person using or suffering to be used any furnace shall, in the event of smoke or ash, grit or other particles being emitted therefrom for periods longer than two minutes in the half-hour, if he is the occupier of the premises, or the fireman or other person employed by such employer, be liable, ... etc."

The provision which constitutes the making of manufacturing smoke a nuisance should be the first and principal clause in the Bill.

The penalties should be on a higher scale. Those inserted in the Government Bill of 1922 were not unsatisfactory. The fireman as well as the owner and manufacturer should be liable under the Act. A clause safeguarding the manufacturer against accidents should be inserted. The regulations in the Act should for the most part be definite rather than merely permissive.

It is important that the Act should include railway trains, steamships, traction engines and all road vehicles, and Government establishments.

It is universally agreed that the small local authorities are ineffective through local influence. They number 1800 and should be concentrated ; but there may be a difference of opinion as

to how this should be done. The recent Bills have allocated it to the County Councils and the County Borough Councils; but County Councils are already very much occupied, and have not been, and would not in the future be, elected mainly on this issue. The County Councils are rather far from the pressure of public opinion, though they are not supposed to be. On the whole, I think that progressive opinion favours an *ad hoc* authority, with delegates from each of the local councils included in it, who would also contribute to its expenses. I do not think that it is practicable to have a special election on this subject, hence this proposal for delegates. South Lancashire might be divided into about three such smoke authorities, and the medical officers of health and the sanitary inspectors should have representatives there. The delegates from local authorities need not be, and often should not be, already members of the authority.

The Board of Health should employ about six or more highly skilled scientific inspectors, whose business would be to keep local authorities up to the mark, with authority to prosecute, at local expense, if the local authority failed to do so. This would necessitate the establishment of a Smoke Committee at Whitehall, with the definite object of reform in view, and it might circulate information, as the Meteorological Office, and to some extent, the Board of Health, do at present.

It has often been held that these inspectors should not commit themselves to advice, lest their advice should fail and the firm be fined for following it. One may admit that care is likely to be needed, and some tact. But the experience of the inspectors at Huddersfield and Sheffield, and still more widely in Salt Lake City and other places in America, would seem to weight the scales of usefulness the other way on the whole.

It is not actually possible to abolish all smoke. Therefore, a slight suspicion of smoke is the ideal usually aimed at. It need not be enough to do much harm to the atmosphere. Manchester allows two minutes in the half-hour of black smoke without prosecuting. This is for stoking up, and I think that so long as we use raw coal and hand stoking it can not be always avoided.

I think that this limitation might be put into the Act. Some think that the Board of Health should set the standard. I should have no hesitation about this if the Board of Health had hitherto shown any zeal for improvement, but it has not. Ever since 1875, its predecessor, the Local Government Board, has had the right to interfere with any local authority which neglected to carry out the Act. The Act has been widely ignored, but the Local Government Board has never once intervened, and rather prides itself upon not having done so. It would, therefore, be safer to put this two minutes' limit per half-hour into the Act itself, with the proviso of appeal before mentioned.

AMERICA.

The chief American cities have taken up smoke abatement seriously. I have received a whole batch of their regulations. One of the striking differences between the slow ways of England and the real wakefulness of America is now found in the state of the air they breathe in their towns.

As a very long typewritten account, with diagrams, of the work in Salt Lake City, has been kindly sent me by the chief official, Mr. H. W. Clark, I think we shall learn most from it as a type of American effort, without giving a great many data from other cities. The agitation began in the winter of 1918-19, though there had been two previous attempts at reform which local and political influence had succeeded in stifling. The U.S. Bureau of Mines was induced to undertake the work. Congress voted 15,000 dollars a year, subject to an equal local levy. This was provided by the State and the City. Mr. Osborn Monnett, the Smoke Abatement Engineer of the City of Chicago, was retained to investigate and report. Private houses were found to contribute 27 per cent. of the smoke. There were heating plants, smelters, railways and other industries. The industrial plants and boilers were in a shocking state, running from 45 to 65 per cent. on the Ringelmann Smoke Chart, whereas in the cities with a reformed atmosphere they are not considered satisfactory above 2 per cent. It was found that the rarefied atmosphere in Salt Lake City, 4500 feet above sea level, required 18 per cent.

more area and 40 feet more height in the chimney than was needed in lower situations, to produce the draught.

A Smoke Ordinance was passed on November 1st, 1920, dealing in some detail with boiler and heating plants and how they should be operated. Any smoke denser than No. 3 on the Ringelmann Chart, lasting for over one minute, violated the law. When fires were being cleaned and new ones built six minutes were allowed.

A Smoke Abatement Department, with a staff of seven during the six winter months, was organised. The cost was ten cents per annum per head.

The inspectors teach the firemen, show them how to stoke, take the shovel themselves, sometimes spend half a day or a whole day in showing how smoke may be avoided. They help as well as warn. Work was organised by January 1st, 1921.

An observer is stationed on the twentieth floor of a building with an outside balcony all round, from which all the city is visible. He telephones to any factory making smoke, and keeps records. Much smoke is made in winter before daylight, so that they had a searchlight to begin with when things were so bad. This had a wonderful psychological effect on stokers. When they saw the light looking at them, they stopped smoke, though often too far off for the rather weak searchlight to penetrate effectively. During what remained of the winter season industrial smoke was reduced by 46 per cent., before the summer season allowed any structural alterations to be made.

It appeared that there were 160 regular violators of the law, and 150 others whose plants needed, and would respond to, reconstruction. These plants were investigated in detail and prescribed for, and the owners approached with persuasion to put them right. The Smoke Department had no compulsory powers. The response was good, and 100 plants were reconstructed or replaced that summer of 1921. The following winter those particular plants reduced their smoke by 84 per cent. Next

winter the railways joined in, and actually paid their own inspectors, first one, and then two, to stop their locomotives smoking. These men were practically additions to the staff of the city.

Police court proceedings were taken in thirteen cases. They were all postponed, to give the owners time to fulfil their promises of conformity.

The following winter, 1921-22, showed manufacturing smoke reduced by 80 per cent. of its original amount in 1920. At the end of the winter some 190 plants still needed alteration, which was carried out during the summer by the same methods in 118 plants, some costing thousands of dollars to bring to the standard. These reformed plants reduced their smoke the following winter by 89·7 per cent.

This winter eleven cases were brought to the police court: two fined £5 each, the other sentences were postponed on promise of amendment as before. One promise was not kept.

The total reduction of industrial smoke since the bad days reached 90 per cent. in the winter of 1922-23.

In 1923 the owners of 136 plants, chiefly churches and boarding houses, were advised on new plants; and the need for maintenance of older improvements was dwelt on. One of the plants remedied this summer was the last of the big ones. It was a stand-by steam plant for making electricity only occasionally used, and its refitting cost more than a quarter of a million dollars.

The fourth winter saw the total reduction up to 93 per cent. With only 7 per cent. left of the smoke of 1920, a minimum must be near. Smoke lasting under a minute is not counted. Only one plant came before the courts.

What is left are the private houses. Advisers were sent round them in some districts in the beginning of 1923, so far as funds allowed, and great local improvement followed. The smoke was halved in the districts inspected. But this must now be made comprehensive, and the lesser evil will no doubt follow

the greater. But the cost of inspection is more than with large industrial plants.

The Salt Lake Weather Bureau reports that the hours of dense smoky weather have gone down since 1920 by 39·3 per cent. and of light smoke 32·2 per cent. They do not discriminate between smoke and fog. These figures are not so striking as the others, because they include the effect of smoke from private houses, still to be tackled effectively.

The coal saved has been calculated from returns asked for. It amounts to about £6000 a year, a good return on the improvements made. Can anyone give a sound reason why Englishmen should not make their cities as fit to live in as they are in America?

J. F. Tangye, Printer, Manchester.

SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN

The Influence of Electricity on the Domestic Smoke Problem

by

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The British Electrical Development Association

EIGHTH SESSION

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ALTHOUGH the influence of electricity on the industrial smoke nuisance cannot be dealt with in this paper, yet the spread of electrification in the world of work has some bearing upon the home problem.

The Manchester Electricity Supply Department, I believe, claims in ten years to have put out of action some three hundred industrial chimney stacks. Salford recently reported 40,000 h.p. electric motors operating in thirty-three different trades.

In America the electricity supply undertakings have already discovered that for highest efficiency and lowest cost the load upon the works must not only be large, but be well balanced; wide use of electricity from the same system for lighting, cooking, heating, and power conduces to the lowest rates for all classes of consumers.

Working men and women to-day are accustomed to the use of electricity in factories for lighting, often for canteen cookery, and almost always for machinery driving. They have seen the evolution of special machines and processes, many of which would have been impossible without the use of electric power, and the more thoughtful of them are already asking why more of the advantages of this form of energy cannot be made available in their own homes.

In the work of improving conditions under which heat energy is used in the home, and so covering a solution of the domestic smoke problem, the electrical industry is running parallel with the gas industry. Naturally, we hold the view that we provide a more complete solution to the problem. In the meantime the competition between these two great public services is to the benefit of the public, and it is to be doubted if without that competition the inventor and manufacturer would have made anything like the progress which the past few years have seen.

In the opinion of the writer, the electrical people have not so far in any general way, and with certain brilliant exceptions, shown a grasp of the essentials for making the most of their business in the way that the gas undertakings have done.

Public services of heat energy are peculiar in this respect, that the consumer has more to do than merely to obtain the connection or service ; he requires appliances, less permanent and more complicated than those needed for the use of water, appliances which require a certain amount of attention to keep in a proper state of efficiency, and some degree of knowledge and intelligence in their use. In addition, we find in both gas and electricity services that the consumer, who after all does not want gas or electricity but the services they render, has to rely upon the assistance of at least three groups within the industry concerned.

1. He wants a continuous service of gas or electricity as cheaply as he can get it.
2. He wants appliances for its conversion into light, heat or power.
3. He wants the " installation " piping, cabling and connecting up, maintenance and repair.

The gas industry is much older than ours, and in most cases has developed a closer supervision over these three activities. Upon this joint working for the good service of the consumer success depends, even more than upon price ; and the work of the inventor and manufacturer, the local business of the installa-

tion contractor, and the sales policy of the gas or electricity undertakings, need to be closely co-ordinated if the best results are to be attained. Many gas undertakings provide brilliant examples of this co-ordination, and to-day the electrical industry is steadily and in some places even rapidly approaching a similar standard.

In the past, however, and in many instances to-day, this close connection has not existed, the electricity supplier thinking only of his consumer in relation to the electricity used and paid for, and the contractor or manufacturer often enough pushing all sorts of appliances and proposals without proper regard to the supply conditions in different districts.

In no other business has the word " Service " so pregnant a meaning, and this is increasingly true as one tackles domestic work. The consumer and consumer's servants have to be instructed tactfully, and by people with a sympathetic knowledge of home conditions. They must be provided with the more expensive items of apparatus on hire or hire-purchase, watched unobtrusively from time to time to see that they are getting the best value out of the method, and supplied with the prime mover, in our case electricity, at reasonable rates, not necessarily cut rates, but certainly on tariffs or charging systems, essentially simple, and not hedged round with scientific trimmings as too often in the past has been the case.

Domestic Lighting is perhaps outside the scope of this paper ; since we passed the day of the torch, no form of artificial lighting can really be accused of making much smoke. We may, however, claim for electricity that it offers a light which is without any effect upon the atmosphere, taking nothing from it and adding nothing to it.

HEATING AND COOKING.

The open fire we probably have to live with for a long time to come, yet, improvement in the design of grates has done much already to reduce the domestic smoke nuisance. The wide use

of the now popular Radiant electric fire is helping also to a large extent by replacing the " short hour " coal fire, the fire lighted to minister to someone's comfort for one hour or less and often taking half an hour to burn into a radiant and smokeless condition, not only wasteful but a cause of labour, smoke and dirt out of all proportion to the benefit derived from it. During the half seasons and in cold summers the electric fire is very largely used, and may already be credited with a good share in reducing domestic smoke.

In cookery the progress so far made by electricity is less, but rapid at the present time. Any electric or gas apparatus which puts the coal range right out of action is a big smoke reducer. Most ranges are stoked very frequently when in action, and generally forced first thing in the morning to get hot water ; fed as they are from the top, they do produce a great deal of smoke until the whole range is hot and working steadily.

We have now in many places all-electric kitchens, or combinations of coke or gas and electricity, or all three, giving the householder separate appliances for the water heating and the cooking, and so reducing the time and conditions of imperfect fuel combustion which produce smoke, the forcing of fires under strong draught in massive ranges of cold iron and brick with the object of heating large quantities of water quickly, or raising to cooking temperature an oven and structure the mass of which is out of all proportion to the food to be prepared.

The dearness of coal is a blessing, if a disguised one ; it has probably changed methods even in cities like Manchester. The writer remembers in earlier days the open roaring fires, with the raised cupboard oven, and the cast-iron kettles and frying pans with walls nearly half an inch thick ; to-day we are able to use an immense variety of utensils in the thinnest metal, and in sizes and shapes to avoid waste, and in many electrical appliances the heat is actually released within the vessel or body of the liquid being heated.

We have been told for thirty years that electric cookery could never be an economic proposition, but the effort of the

engineers to apply a relatively expensive form of heat energy to this important work has not only been successful, but has forced upon them so close a study of the use of heat that their work has had a good influence on the design of all cooking and heating appliances, and is now beginning to affect even the working methods of the conservative housewife and chef.

In short, the electric method teaches us not only to use heat efficiently but to do with less of it by alteration in method ; the air-tight electric oven, capable of roasting meat with one-fifth to one-eighth of a unit of electricity per pound weight, is an example ; the heat may be of a finer or dearer texture, so to speak, but it acts inside the oven close to the meat, and very little of it is lost. As a striking example of this local application of heat for which the electric method is distinguished, consider electric welding ; here metal parts are joined together by heat actually evolved in the metal at the point of juncture, a striking comparison with the older ways of the smith and his forge.

So far electric cookery apparatus, at least the range, has evolved on lines similar to gas apparatus, even as that evolved out of the coal fire cookers which preceded it ; as usual, a compromise, something better but not too much unlike the appliances which it replaced.

With our method, however, there is more room for departure from existing ways of cooking food, and slowly kitchen methods will change and take the fullest advantage of the ease of direct heat application, and of the facility for dividing up heat applications to cookery, which electricity affords. When we consider the very small amount of heat energy which is really absorbed by a given quantity of raw food to bring about the physical and chemical changes which make the difference between raw and cooked, it is obvious that there is room for great progress yet, and that progress will probably be easier with electricity than with any other medium.

Already progress has been made in heat storage cookery, " haybox " and similar devices, but there is little " internation-

alism " amongst cooks or in the manner of serving food. Each country has its methods, the kitchens and the stomachs have grown up together, so to speak, and the reformer may find it easier to mould the religious or political opinions of a people than to make them eat stew when they have been reared on roast.

Perhaps, in future, the coal, gas and electric methods of individual cookery will be in competition with mass cookery and the distribution of hot food. This sort of thing is happening to-day on a small scale in service flats, canteens and restaurants.

The writer ventures to hope this will not be the solution, that it will rather lie in the scattering of individual dwellings, the opening out of cities, and the distribution by electricity of light and heat, perhaps supplemented by some smokeless fuel, and power for production and transport.

HOME HEATING.

Now, although we are all to some small degree reducing domestic smoke, we are not reducing chimneys ; so far very little change has taken place in house design to suit the newer methods of lighting and heating.

The architect to-day has a kindly feeling for chimneys and often he weaves them into his designs with skill, but when we can assure him that the last chimney has gone cold, his imagination will take a leap, providing roof gardens and other features of beauty, and we may for the first time become familiar with those " Tilescapes " at present only enjoyed by airmen and cats.

In new houses, costing, for structure only, from £750 to £1500, some 3 to 5 per cent. can be saved by omitting chimneys from bed and other rooms where continuous artificial heating in winter is not needed, thus saving on building material and labour for features seldom used on account of the trouble involved ; this will pay for the electrical equipment to replace them, and offer the occupant something he can use with comfort and satisfaction.

Architects seem to be anticipating changes so far as coal cellars are concerned, they get smaller, the wash copper also is often left out.

In the kitchen the use of an electric range gives more freedom in planning. The position of the coal range is often fixed by consideration for the chimney stack, whereas the electric can stand in a good daylight and be adjacent to dresser or sink, no small matter to those who work in the kitchen year in and year out.

Change in methods of water heating may also have a bearing on design. The electric heat storage method points to subdivision of hot water supplies about the house, separate tanks for sink, baths, etc., cutting out all the wasteful hot water distribution and leaving only cold water pipes and electric wires to consider.

Generally, the engineering equipment of the house has developed, and it is to develop so much more, that the time seems at hand to consider the design of structures in relation to the equipment. It is still all the other way, and even in a well-found house the latest appliances of the gas and the electrical engineer often look like excresences for which the architect had no great welcome.

The problem of home heating will probably be found less simple than the mere substitution of one form of heat energy for another—gas for coal, electricity for gas—and it will be solved rather by a study of fresh methods of keeping the heat losses from the human body within the limits required for health and comfort.

So far we have no general practical way of portable heating, excluding the special work done in this direction for airmen ; we have not yet produced any body-heating appliance which we can carry about with us all the time, and must, in the open air, rely upon clothing or " lagging " to retain the natural heat of the body.

Indoors we achieve the desired effect partly by radiant heat and more extensively by trying to keep the air temperature above the outside level; in short, by raising a room and its contained air to a temperature which may in winter be 30° F. above its surroundings, and then releasing into it continually enough heat energy to make up losses arising from leaks and ventilation and the conductivity of the structure.

We are apt to think that primitive people relied entirely upon radiant heat, the sun or some open fire, but in the earliest dwellings one sometimes finds an example of efficient and extremely economical convective heating. I refer to the arrangement where the cattle were housed during the winter in a sort of basement over which the owners lived. The people entered by going up some few steps, and so the dwelling or sleeping place was above the source of heat, giving them, with the exception of the crannies which must have amply provided for ventilation, a sort of diving bell or warm air pocket in which to rest, and there may yet be a hint in this method for the architect and the heating engineer.

Recently, the papers have referred at some length to the discovery of Roman ruins, in which the rooms were heated by a furnace under the floor, and they evidently had seized one important principle, that comfort comes from a higher temperature around the feet than around the head.

In the last few years much attention has been directed to the value of artificial heat in radiant form, the desirability of living and working in an air temperature relatively low, and obtaining the additional heat necessary by radiation from bright fires of coal, gas or electricity. In the writer's opinion there has been a tendency to overwork this idea. Artificial heat requirements vary so much with constitution, with the nature of one's occupation, and to some extent with temperament, besides depending a good deal on the moisture or dryness of the air.

It does appear that for most people a mixture of radiant and convective heat would be the most satisfactory, an ambient temperature something a little below the line of comfort perhaps, supplemented by bright and cheerful sources of radiant heat. In this connection the work of Dr. Margaret Fishenden is of great interest and probably familiar to many here.

Latterly, a good deal of attention has again been directed to the combination of heat and light, the so-called Sun Ray heating, in which high temperature filaments giving off short wave length radiation, and shielded from the eye, are used to warm the body or floor surfaces and coverings, and at the same time spread a good deal of cheerful and stimulating light.

Obviously, the subject of artificial heating is of vast importance and will repay study. It closely touches the smoke problem. In the average middle class house, well-built, furnished and used in such a way that heat losses are not great, we are still burning 2½ to 3 lbs. of good coal per hour for perhaps twelve or sixteen hours a day in winter, and in order to maintain comfortable conditions for two or three persons in one room.

In this city, Manchester, you have the advantage of very simple tariffs and low rates for electricity used in the home. A small annual charge based upon rateable value, and in itself generally not greater than the usual expenditure on the electric lighting alone, enables you to purchase electrical energy for every purpose at the present time, I believe, at a halfpenny per unit, through a single meter, permitting a simple installation of wiring, and the use of small electrical appliances for heating or labour saving in any part of the house, in addition of course to fires and cooking ranges.

This method of charging is spreading rapidly throughout the country, and in many districts it is found that houses, still relying perhaps on coal for their heaviest heating work, are now able to do all of their cooking and some of their heating, much labour saving and all lighting, for an addition of perhaps 50 to

75 per cent. to the amount which they have been in the habit of paying for electric lighting alone.

A middle class family of five persons will carry out the usual cookery with an electric range for one unit of electricity per head per day ; say, 36 units per week at a halfpenny per unit, 1s. 6d.

Your tariffs, together with the great profits earned by the undertaking, show what can be done under keen management with modern generating plant, and a very big output of " mixed " load—lighting, factory power, transport and domestic heating.

If some consumers are able to do this, why not all ? Neither cost nor quality of the cookery can be against the method.

The answer is that to make the use of electricity general in the land a low rate alone is insufficient. Several other considerations have to be grappled with in an ungrudging and long-sighted manner.

When we should talk ironmongery we talk amperes, and so far very little real advertising has been done. The immediate essentials are :—

Firstly, " Service " to the Consumer.

A.—Clear and simple advertising.

B.—Plenty of actual demonstration in use.

C.—Hire or easy terms for the appliances and wiring.

D.—Tactful inspection and proper maintenance in use.

E.—A reasonable rate for electricity and a simple tariff system.

Lastly, " Service " to the Consumer.

The message to-day of the electrical industry to the householder is based upon a mixture of raw fuel and electricity. The raw fuel to be good coal, coke or smokeless fuel, consumed in one or two grates or furnaces in each house and employed for the heavy work of water and room heating, so reducing to a minimum

the labour attendant upon the use of fires, the storage and cartage of fuel and the emission of smoke and grit ; beyond this, to rely upon electricity for short period heating, cookery of food, lighting and labour saving by electrically-driven machines.

These proposals are being carried out where the rates for electricity are suitable ; where less suitable, the exact economic mixture depends upon circumstances and the house owner's views, whether he thinks it is worth while to pay a little more for cleanliness and comfort, and so on.

The differences in electricity conditions up and down the country make it difficult to generalise, as people so frequently do, on the dearness or cheapness of the electric method. We contend, and I think properly, that we need not offer the electric service at the same price as gas or raw fuel, it is worth something more ; but I am aware that the factor by which you may multiply it is a variable one. When you offer a person something better than he has had, you can never get from him the full value of the betterment. To do business each side must gain something. Also, there is a great difference of opinion amongst people as to the value of improved home conditions. The truly thrifty may be willing to spend more than those whose ideas of economy are limited to reducing bills. However, generally speaking, it is obvious that the cost of electric service to the user is " falling " whilst its advantages are rising. The fitments and furnishings of houses do not get cheaper, labour does not become easier, and it is more and more a case for cutting out work, lengthening the life of goods, and arranging one's affairs so that toil, drudgery, danger and delay are reduced wherever possible.

It is difficult to overestimate the value of any work being done to reduce the smoke nuisance ; its success means more than the clearing of the atmosphere, for in a general way smoke reduction indicates increase in the efficiency of use of heat energy, a vital matter to people who are always drawing upon reserves of fuel which cannot be replaced, and may live to see the day

when waste of heat will be more reprehensible than waste of bread.

It has been stated by some experts that some six per cent. of the weight of coal burnt in domestic grates falls back in the form of soot. It is interesting to speculate upon this, bearing in mind the total weight of coal which has been destroyed in the domestic grate since we started using that form of fuel. We must be making the world lighter in weight and larger in diameter —a point which we may commend to the attention of the astronomers !

J. F. Tangye, Printer
Manchester

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SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN

OFFICIAL PROGRAMME

OF

Smoke Abatement Conference

November 4th, 5th and 6th, 1924

AN

International Smoke Abatement Exhibition

is being arranged for NOVEMBER, 1925. This will be organised to demonstrate all the methods by which industrial and domestic smoke can be abated in a practical way. At the same time as this Exhibition an important

SMOKE ABATEMENT CONFERENCE

will be held, which will provide an opportunity for an exhaustive survey of the subject from many aspects. It is hoped that the Conference and Exhibition will be complementary and complete.

Ample support has already been promised from abroad and at home. Firms, organisations and individuals are invited to communicate with the Hon. Secretary, 33, Blackfriars Street, Manchester.

Have you read the advertisements following the Programme?

You will find something of interest

(See page 35)

SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN

Conference on Smoke Abatement

to be held in the

LORD MAYOR'S PARLOUR, TOWN HALL, MANCHESTER

On NOVEMBER 4th, 5th and 6th, 1924

in connection with a

SMOKE ABATEMENT EXHIBITION

In the CITY HALL, DEANSGATE, MANCHESTER, Nov. 4th to 15th inclusive

For Lectures at the Exhibition, see Page 35

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Alfred Saxon, Esq., M.I.Mech.E., Past-President, Messrs. George Saxon, Ltd., Openshaw

Manchester and Salford Sanitary Association:

Evan Roberts, Jnr., Esq., M.B.E.
Rev. J. J. Wilson, Hon. Sec.
Dr. A. W. Martin
J. H. Howson Ray, Esq., F.R.C.S.
Mrs. Barratt
Miss Moorehouse

National Gas Council:

Samuel Tagg, Esq., M.Inst.C.E., Engineer and Manager, Preston Gas Works
G. S. Frith, Esq., Engineer and Secretary, Runcorn Gas Co.
F. A. Pye, Esq., Secretary and General Manager, Chester United Gas Co.
W. J. Smith, Esq., B.Sc., Engineer and Manager, Bolton Corporation Gas Works
Ralph E. Gibson, Esq., Engineer, Liverpool Gas Co.

Manchester Society of Architects:

A. J. Hope, Esq., F.R.I.B.A., President
H. S. Fairhurst, Esq., A.R.I.B.A., Vice-President
F. B. Dunkerley, Esq., F.R.I.B.A.

Royal Sanitary Institute:

Dr. R. Veitch Clark, M.A., M.B., Ch.B., D.P.H., LL.D., M.O.H., Manchester

Sanitary Inspectors' Association:

R. Morton L. Rowe, Esq., Manchester

A. E. Crossley, Esq., Bramhall, Cheshire

Society for Protection of Ancient Buildings and Works of Art:

A. R. Powys, Esq., Secretary, London

Society of British Gas Industries:

J. Wilfrid Drake, Esq., Messrs. Drakes, Ltd., Halifax
B. B. Waller, Esq., A.M.Inst.C,E., Messrs. Phœnix Works, Stroud, Glos.
R. B. Hodgson, Esq., M.I.Mech.E., Messrs. Ashmore, Benson, Pease & Co., Ltd., Stockton-on-Tees

Society of Chemical Industry:

E. V. Evans, Esq., Hon. Treasurer

Society of Chemical Industry, Chemical Engineering Group

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H. Cheetham, Esq.
A. E. Maltan, Esq., Esq., M.I.Chem.E.
H. Talbot, Esq., B.Sc., A.R.C.Sc., Hon. Secretary

Society of Chemical Industry (Manchester Branch)

R. H. Clayton, Esq., Didsbury

J. Porter Shenton, Esq., Chorlton-cum-Hardy

Society of Engineers:

J. O. Nichol, Esq., B.Sc. (Eng.), Manchester

Society of Medical Officers of Health:

Dr. T. W. N. Barlow, O.B.E., M.O.H., Wallasey
Dr. R. Veitch Clark, M.A., M.B., Ch.B., D.P.H., LL.D., M.O.H., Manchester
Dr. Cyril Banks, M.O.H., Halifax

Delegates appointed by Local Authorities

Birkenhead—Councillor Tweedale
Blackburn—Alderman Fielding
,, Dr. W. A. Darley, M.O.H.
Blackpool—E. W. Rees Jones, M.D., D.P.H., M.O.H.
Bootle—Councillor Harry Pennington
Bristol—Councillor A. E. Hill
,, J. A. Robinson, Esq., Chief Sanitary Inspector
Burnley—Alderman Keighley
,, Councillor Lees
Bury—Councillor Johnson
,, Dr. G. G. Buckley, M.O.H.
Chester—S. H. Moore, Esq., Chief Sanitary Inspector
Halifax—Ald. Branson, Chairman of Health Committee
,, Coun. Foster, Vice-Chairman ,, ,,
,, Alderman Waddington
,, Councillor Greenwood
,, Dr. Cyril Banks, M.O.H.
,, H. G. Clinch, Esq., Chief Smoke Inspector
Leeds—Councillor George F. Kelly
,, Councillor Benjamin Green
Leicester—Councillor Wilford, Chairman, Health Committee
,, Councillor Folwell, Vice-Chairman, Health Committee
Liverpool—Alderman William Muirhead
,, A. A. Mussan, M.D., M.O.H.
Motherwell & Wishaw—The Provost
,, ,, A. G. Stewart, Esq., Town [Clerk
Newcastle-on-Tyne—Coun. R. W. Simpson, Chairman, Health Committee
,, ,, Coun. D. Adams, Vice-Chairman, Health Committee
,, ,, Dr. H. Kerr, M.O.H.
Oldham—Councillor Cheetham, J.P., Mayor
Oldham—Councillor Bolton
,, ,, Wrigley
,, Dr. Wilkinson, M.O.H.
,, G. Winterbottom, Esq., Chief Insp. of Nuis.
Portsmouth—Ald. Sir George Couzens, K.L.H., J.P.
Preston—Councillor R. Durham
,, Councillor Derham
,, Dr. F. A. Sharpe, M.O.H.
Rochdale—Alderman Edward Thomas
,, Dr. A. G. Anderson, M.O.H..
,, W. H. Hickson, Esq., Town Clerk
Rotherham—Alderman W. Wormald, Chairman, Public Health Department
,, Councillor J. Clarke, Vice-Chairman, Public Health Department
,, Dr. A. Robertson, M.O.H.
Salford—J. P. Cargill, Esq., Chief Sanitary Inspector
,, J. D. Eldson, Esq., Borough Analyst
Stoke-on-Trent—G. Petgrave Johnson, Esq., M.O.H.
Swansea—Coun. David Williams, Chairman, Health Committee
,, Alderman William Owen, Vice-Chairman, Health Committee
,, Thomas Evans, Esq., M.B., D.P.H., M.O.H.
Wakefield—Dr. T. Gibson, M.D., D.P.H., M.O.H.
Wallasey—Councillor D. P. Charlesworth
,, Councillor Nurse McFall
,, Dr. T. W. Naylor, M.O.H.
Walsall—Alderman C. C. Walker, Chairman, Health Committee
,, Dr. J. A. M. Clark, M.O.H.
,, A. T. Hubble, Esq., Chief Sanitary Inspector
Wrexham—Ivor A. Stephenson, M.S.I.A., Sanitary Inspector

SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN

THE Smoke Abatement League of Great Britain was founded at a Smoke Conference at Sheffield in 1909, and was active until the war stopped its operations at the close of 1914. It was revived in 1923 and is now continuing its work with renewed energy and directness of purpose. Although the reasons for smoke abatement have been conclusively demonstrated in the past, yet vigorous and widespread propaganda is necessary to prevent apathy and to stimulate public opinion. The League has in active preparation a comprehensive programme on a scale commensurate with the size of the general problem.

The two questions, "Why stop smoke?" and "How stop smoke?" require considerable thought, but the League hopes to give more attention to the practical side than has hitherto been the case with the many enthusiastic bodies which have become as invisible as the air that they set out to purify. The splendid exception to this dismal list is the Coal Smoke Abatement Society, London, which has done and is doing much valuable work. To allay confusion, it must be explained that the Society operates in the Metropolis and its immediate vicinity, while the League works in the provinces. Both bodies are in constant touch.

The technical problems involved are many and often difficult. There has been much ado about the relative amounts of and proportionate damage due to industrial and domestic smoke. The League aims at the prevention of smoke in general, without any discrimination. The methods available for smoke abatement call for individual treatment in each particular case. The League is not a technical body but aims at securing the co-operation of qualified persons, and also hopes to find a service in organising information and crystallising opinion.

To carry out its work on anything like the scale contemplated and as already in great part commenced, it is essential that the income of the League should be considerably increased, and those who would like to become members, or who desire any information, are invited to write to the Hon. Secretary, 33, Blackfriars Street, Manchester.

THE SPECIAL ATTENTION OF ALL VISITORS TO THE CONFERENCE

is drawn to the following Rules for the

GENERAL CONDUCT OF THE MEETINGS.

THESE RULES have been devised to expedite the proceedings, to introduce order into the discussions, to eliminate irrelevant and frivolous matter and generally to make the discussions informative and useful to all who attend. It is believed that observance of these Rules, as far as practicable, is to the advantage of everybody concerned.

(1) The Papers will, as far as practicable, be taken in the order in which they appear on the Programme. In the discussion following each Paper, there will be no order of precedence, and it will be the exception to call upon anyone to open the discussion. Questions to elucidate possible ambiguous points will usually be asked for and taken before the general discussion.

(2) Printed slips will be available at the meetings upon which those wishing to take part in the discussion should fill in their name, address, profession and, if applicable, the nature of their firm's business. These slips are to be transmitted to the Chairman, who may, at his discretion, call upon speakers in the order he thinks best or in the order in which the slips are received by him.

(3) Speakers should confine their remarks strictly to the subject under discussion, speak audibly and distinctly, and be **as brief and concise as possible.** No speaker should continue for more than ten minutes without obtaining the consent of the Chairman to do so after his time has elapsed. It is suggested that thanks to the Author and complimentary remarks on his work should be the Chairman's privilege. Criticism should, as far as possible, be constructive and not destructive.

(4) Those who are unable to be present at the meetings and wish to take part in the discussion are invited to submit their contributions in writing. Illustrations, curves and diagrams may be included. Contributions sent prior to the meeting may, at the Chairman's discretion, be read out to the meeting, either in full or in abstract.

(5) The Author may make his reply to each speaker immediately after the latter has finished, or at the close of the discussion, at his discretion. Speakers may make a second contribution to the discussion at the Chairman's discretion, and if time permits.

Programme of Conference

TUESDAY, November 4th

10-0 a.m. **BUSINESS MEETING of the Smoke Abatement League of Great Britain,** to be held in the Conference Room in the Gallery of the City Hall, Deansgate, Manchester. For Members only

BUSINESS.

Election of Officers
Passing of Accounts
Report
Any other business that may arise

All are welcome who will join the League at the time. The minimum subscription is 2/6, **but larger amounts will enable the League to do more valuable work in Smoke Abatement**

11-30 a.m. **OPENING OF THE EXHIBITION** by the Rt. Hon. the LORD MAYOR of MANCHESTER, Alderman W. T. JACKSON, J.P., President of the Exhibition

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1-0 p.m. **LUNCH** for Municipal Delegates at the Town Hall, by kind invitation of the Public Health Committee of the Corporation

2-0 to 4-0 p.m. **OPENING SESSION OF THE CONFERENCE**

Chairman - - Dr. R. VEITCH CLARK, M.A., M.B., Ch.B., D.P.H., LL.D., M.O.H.
(Medical Officer of Health, Manchester)

LEGISLATION—

"Smoke Legislation in England and America," by J. W. GRAHAM, M.A., Chairman of the League

"The Possibilities of Smoke Prevention under the P.H.A., 1875," by R. MORTON ROWE, Chief Smoke Inspector, Manchester

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4-30 to 6-0 p.m. **SECOND SESSION of the Conference**

Chairman - Councillor WILL MELLAND, J.P., Hon. Treasurer of the League

"Air Pollution," by Dr. J. S. OWENS, Honorary Secretary to the Advisory Committee on Atmospheric Pollution, Meteorological Office, Air Ministry

"Diagrams on measuring Atmospheric Pollution in a Lancashire Town," by Dr. J. R. ASHWORTH, of Rochdale

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7-30 to 9-30 p.m. **THIRD SESSION of the Conference**

Chairman - - Councillor E. D. Simon, M.P.

"The effect of Atmospheric Impurities on Buildings," by Sir FRANK BAINES, Director of H.M. Office of Works. (Illustrated by lantern slides)

"The Work of the Departmental Committee on Smoke Abatement," by Prof. COHEN, of Leeds, with slides illustrating the damage done to plants by smoke

WEDNESDAY, November 5th

Morning Visit to the Bradford Road Gas Works of the Manchester Corporation, by kind permission of the Chairman and Members of the Gas Committee

Visitors and members who wish to take part in this visit are requested to communicate as soon as possible with the Hon. Secretary of the League. The numbers will be limited

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2-0 to 4-0 p.m. FOURTH SESSION of the Conference

Chairman - Alderman Sir WILLIAM KAY, J.P.

(Chairman of the Manchester Corporation Gas Committee)

LOW TEMPERATURE CARBONISATION AND SMOKELESS FUEL

"A Description of the Smokeless Fuel Plant for Glasgow," by ROBERT MACLAURIN

"Some New Aspects of Low Temperature Distillation," by HARALD NIELSEN, M.Inst.Chem.E., F.C.S., A.M.I.M.E.

"Coalite," Standard Smokeless Fuel—Town Gas and Oil Supply, by The Rt. Hon. GEORGE H. ROBERTS, P.C., and P. C. POPE

4-30 to 6-0 p.m. FIFTH SESSION of the Conference

Chairman - - H. A. des VŒUX, M.D.

(Coal Smoke Abatement Society)

THE EFFECT OF LIGHT ON HEALTH

Papers by LEONARD HILL, M.B., F.R.S., Director of the Department of Applied Physiology at the National Institute of Medical Research, and by Dr. R. VEITCH CLARK, M.A., M.B., Ch.B., D.P.H., LL.D. (Aberd.), Medical Officer of Health, Manchester

7-30 to 9-30 p.m. SIXTH SESSION of the Conference

Chairman - DANIEL ADAMSON, M.Inst.C.E., M.I.E.E.

(Vice-President of the Institution of Mechanical Engineers)

SMOKE ABATEMENT, FROM THE MECHANICAL ENGINEER'S POINT OF VIEW

"The Complete Gasification of Coal, its bearing upon Smoke Prevention and Fuel Economy," by T. ROLAND WOLLASTON, M.I.M.E., M.S.C.I.

"Pulverised Coal," by J. T. DUNN, D.Sc., F.I.C.

The Smoke Inspector and the Cost of Production," by H. G. CLINCH, Chief Smoke Inspector, Halifax

"Smoke Abatement and Boiler Room Economies in relation to the Training of Boiler Firemen," by JAS. T. HODGSON, M.I.Mech.E., Lecturer on the Management of Stationary Boilers and Smoke Abatement in the College of Technology, Manchester

"Boiler Design," by W. H. CASMEY, of Wakefield

THURSDAY, November 6th

Morning Visit to the Barton Power Station of the Manchester Corporation, by kind permission of the Chairman and Members of the Electricity Committee

Visitors and members who wish to take part in this visit are requested to communicate as soon as possible with the Hon. Secretary of the League. The numbers will be limited

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2-0 to 4-0 p.m. SEVENTH SESSION of the Conference

Chairman - - - SAMUEL TAGG, M.Inst.C.E.
(Past President of the Institution of Gas Engineers)

THE USE OF GAS IN SMOKE ABATEMENT

"Gas Undertakings as Fuel Providers," by Sir ARTHUR DUCKHAM, K.C.B., M.I.C.E., President of the Institution of Chemical Engineers

"The Fuel of the Future," by FRANCIS WILLIAM GOODENOUGH, Executive Chairman of the British Commercial Gas Association, Joint Hon. Secretary of the National Gas Council

"Gas Coke—In relation to Industrial and Domestic Smoke Prevention and Fuel Economy," by E. W. L. NICOL, Assoc. Inst. C.E., M.I.Mar.E., A.M.I.E.E., Engineer and Fuel Expert to the London Coke Committee

4-30 to 6-0 p.m. EIGHTH SESSION of the Conference

Chairman - Alderman WILLIAM WALKER, M.I.E.E., M.I.Mech.E.

THE USE OF ELECTRICITY IN SMOKE ABATEMENT

"How Electricity can help in Smoke Abatement," by JULIUS FRITH, M.Sc., M.I.E.E., M.Cons.E.

"The Influence of Electricity on the Domestic Smoke Problem," by J. W. BEAUCHAMP, M.I.E.E., Director and Secretary, The British Electrical Development Association

"The Use of Power other than that produced by Coal," by Professor MILES WALKER, M.A., D.Sc.

7-30 to 9-30 p.m. NINTH SESSION of the Conference

POPULAR LECTURE by Ex-Bailie W. B. SMITH, O.B.E., Glasgow, on "The Cost of a Smoky Atmosphere." Illustrated by lantern slides

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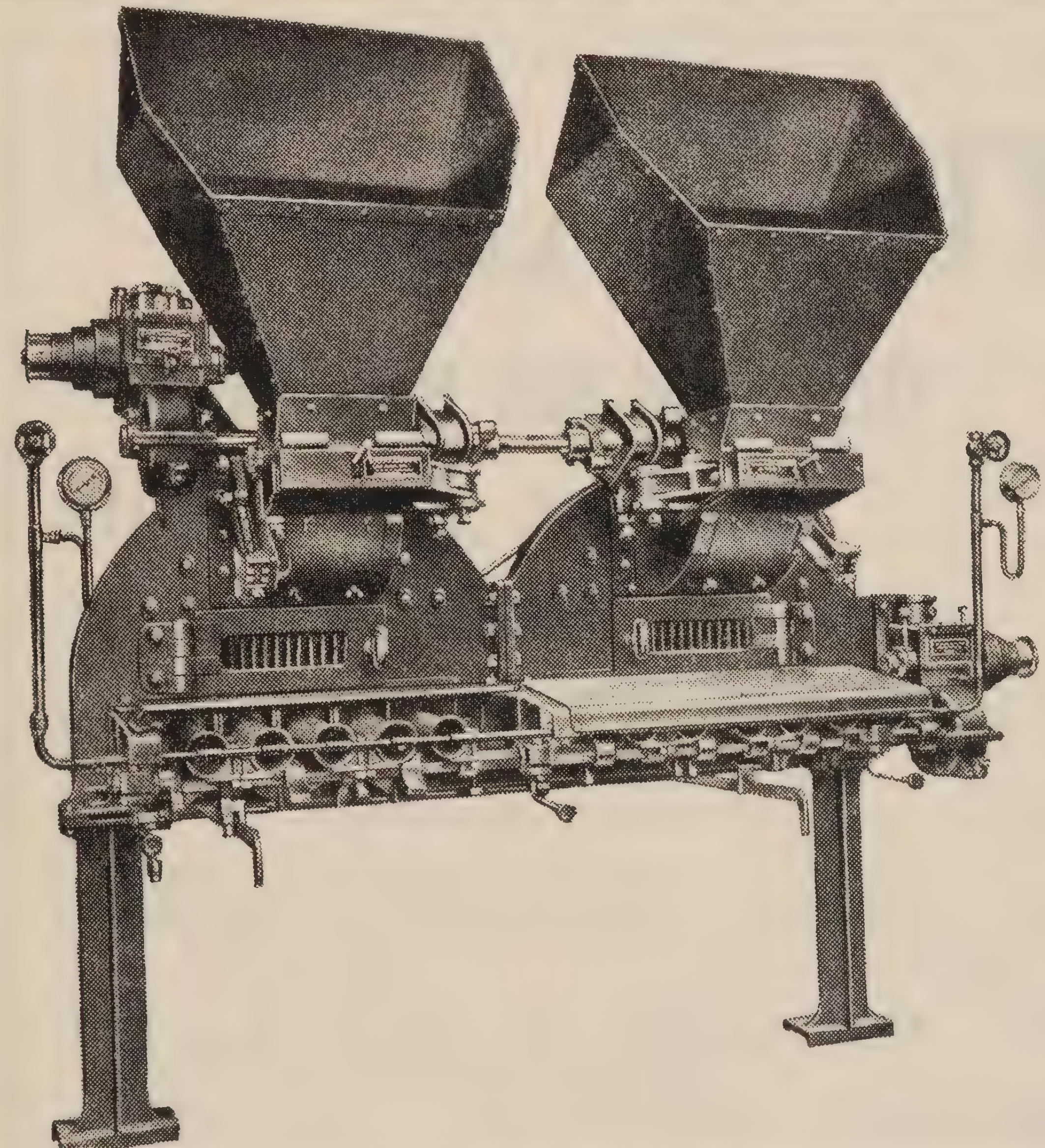
Names of new members of the League will be gladly taken and subscriptions received by

J. W. GRAHAM, M.A., Chairman

W. MELLAND, J.P., Hon. Treasurer

CYRIL ELLIOTT, B.Sc., A.M.Inst.C.E., Hon. Secretary of the League and Hon. Organising Secretary for the Exhibition, 33, Blackfriars Street, Manchester. 'Phone: Central 355



Lectures to be given at the Smoke Abatement Exhibition, City Hall, Deansgate

FRIDAY
Nov. 7th.

Afternoon at 3-30.

"Oil Fuel and Smoke Abatement," by James Kewley, M.A., F.I.C., M.Inst.P.T.

Evening at 7-30.

by Julius Frith, M.Sc., M.I.E.E., M.Cons.E.

MONDAY
Nov. 10th.

Afternoon at 3-30.

"The Origin, Preparation and Combustion of Powdered Coal," by H. Jackson, Assoc. M.C.T., A.M.I.Mech.E.

Evening at 7-30.

"The Origin, Preparation and Combustion of Powdered Coal," by H. Jackson, Assoc. M.C.T., A.M.I.Mech.E.

TUESDAY
Nov. 11th.

Afternoon at 3-30.

"The Economic value of Good Lighting in Industry," by W. E. Bush, (Electric Lamp Manufacturers' Assoc. of Great Britain, Ltd.)

Evening at 7-30.

"The Importance of Good Lighting in Commerce," by W. E. Bush, (Electric Lamp Manufacturers Assoc. of Great Britain, Ltd,)

WEDNESDAY
Nov. 12th.

Afternoon at 3-30.

"The Economic Value of Good Lighting in Industry," by W. E. Bush, (Electric Lamp Manufacturers' Assoc. of Great Britain, Ltd.)

Evening at 7-30.

"The Importance of Good Lighting in Commerce," by W. E. Bush, (Electric Lamp Manufacturers' Assoc. of Great Britain, Ltd.)

THURSDAY
Nov. 13th.

Afternoon at 3-30.

"Theory and Practice of Forced Draught Furnaces," by A. B. Scorer, A.M.I.C.E., A.M.I.Mech.E.

Evening at 7-30.

"Some Notes on Recent Developments in Steam Generation," by Major Gregson, (late R.E.) B.Sc., A.M.Inst.C.E., A.M.I.Mech.E.

FRIDAY
Nov. 14th.

Afternoon at 3-30.

"Gas in the Home," by Hamilton Davies, Esq., B.Sc.

Evening at 7-30.

"Domestic Heating by Gas," by Hamilton Davies, Esq., B.Sc.

Now that we have talked matters over, what are YOU going to do ?

Are you going to contribute to the League or are you willing to work?

There is great need for financial help and plenty of good work to be done.

WHAT ABOUT IT?

A man was hanged in the 14th century for causing a Smoke Nuisance. Some people nowadays deserve the same punishment. DO YOU?

See the . . .

SPECIAL GAS AND ELECTRICAL DISPLAYS AND THE STANDS OF THE LEADING FIRMS

AT THE

Smoke Abatement Exhibition

City Exhibition Hall, Deansgate, Manchester

TUESDAY, Nov. 4th to SATURDAY, Nov. 15th, 1924

J. F. Tangye, Printer, Manchest

SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN

CONFERENCE PROCEEDINGS
NOV. 21st & 22nd, 1911

Smoke Abatement League

OF

GREAT BRITAIN.

PROCEEDINGS

OF

CONFERENCE

Held at MANCHESTER,
November 21 and 22, 1911.

SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN.

LIST OF OFFICERS.

President of the League:
A. Gordon C. Harvey, Esq., M.P., Rochdale.

Chairman:
Principal J. W. Graham, M.A.,
Dalton Hall, Manchester.

Honorary Secretary:
Ernest D. Simon, Esq., M.I.M.E.,
20, Mount Street, Manchester.

Executive Committee:

J. Allan, Esq., Warrington.
Alderman Bennett, Warrington.
Sir John E. Bingham, Bart., Sheffield.
Professor Cohen, Leeds.
Peter Fyfe, Esq., Chief Sanitary Inspector, Glasgow.
A. Gordon C. Harvey, Esq., M.P., Rochdale.
Alderman Hey, Halifax.
Mrs. Higgs, Oldham.
Wilfred Irwin, Esq., Flimby, near Maryport.
Councillor James Johnston, J.P., Manchester.
J. Macaulay, Esq., Chief Smoke Inspector, Liverpool.
Provost Muir Mackean, Paisley.
Slater Nicholson, Esq., Chief Smoke Inspector, Bradford.
Alderman Parks, Mayor of Bury.
John Robertson, Esq., M.D., M.O.H., Birmingham.
R. J. Rogers, Esq., Birmingham.
W. Sinclair, Esq., Sheffield.
Councillor E. J. Smith, Bradford.
Councillor W. B. Smith, Glasgow.
George Ward, Esq., Chief Smoke Inspector, Belfast.
H. R. Watling, Esq., Bradford.

LIST OF CONTENTS.

PROCEEDINGS OF THE CONFERENCE.

INTRODUCTION.

The papers published in this volume were read at a Conference organised by the Smoke Abatement League of Great Britain, held in the Lord Mayor's Parlour, Town Hall, Manchester, on the 21st and 22nd November, 1911. Delegates were present from the following municipalities and societies :—

LIST OF DELEGATES.

Bacup.—Dr. Brown (M.O.H.).
Bury.—Alderman Parks (Mayor of Bury).
Dr. Buckley (M.O.H.).
Bradford.—Chairman and Vice-Chairman of the Health Committee, the Assistant-Solicitor, and Smoke Inspector.
Belfast.—Councillors Clements and McClure.
Mr. Ward (Sanitary Inspector).
Alderman Craig (Chairman Belfast Gas Committee).
Councillor Squire (Vice-Chairman).
Mr. J. D. Smith (Manager of the Gas Works).
Coatbridge.—Provost Davidson.
Cambridge.—Councillor Smith.
Glasgow.—Inspector Fyfe, and Councillor Smith.
Dewsbury.—Chairman of the Health Committee.
Sanitary Inspector.
Halifax.—Alderman Hey (Chairman of the Health Committee).
Harrogate.—Mr. C. E. Rivers (Borough Surveyor).
Leith.—Mr. Bishop (Sanitary Inspector).
Liverpool.—Mr. Macaulay (Chief Smoke Inspector).
Leeds.—Alderman Clark.
Councillor Bedford.
Manchester.—Alderman Fildes (Chairman Health Committee).
Councillor Johnston.
Councillor Jackson.
Middlesbrough.—George Anderson (Sanitary Inspector).
Oldham.—Councillor Isherwood (Mayor of Oldham).
Councillor Simister.
Dr. Wilkinson (M.O.H.).
Paisley.—Provost Muir Mackean.
Perth.—Bailie Charles Scott.
Duncan Cumming (Sanitary Inspector).
Ex-Bailie Forrest.
Ex-Bailie Wright.

Rawtenstall.—The Mayor of Rawtenstall.
Alderman Farran.
Councillor Stansfield.
Councillor Howarth,
Rochdale.—Alderman Collinge.
Councillor Shawcross.
The Medical Officer of Health.
Stoke-on-Trent.—Mr. Jackson (Smoke Inspector).
Widnes.—Mr. Isaac Carr.
Warrington.—Alderman Evans (Chairman of the Health Committee).
Alderman Burton (Deputy-Chairman of the Health Committee).
Mr. Flood (Chief Inspector of Nuisances).
Alderman Bennett.
Dr. Hibbert (M.O.H.).
York.—Councillor Davies.
Dr. Smith (M.O.H.).

SOCIETIES.

Royal Society of British Architects :
Percy Worthington, Esq., F.R.I.B.A.
Edgar Wood, Esq.
Manchester Society of Architects :
John Brooke, Esq.
Paul Ogden, Esq.
Society of Chemical Industries, Manchester Section :
R. H. Clayton, Esq.
W. Thomson, Esq.
Royal Sanitary Institute, London :
Professor Radcliffe.
Institution of Mechanical Engineers :
C. E. Stromeyer, Esq.
Society of Dyers' and Colourists—Manchester Section :
W. Marshall, Esq.
Professor Knecht.
Chemical Society, London :
Professor Cohen, Leeds University.
Professor Smithells, Leeds University.
Professor Dixon, Manchester University.
Cheshire County Council :
Meredith Young, Esq. (County Medical Officer).

It has not been possible to print in full the discussions which took place on the various papers, but the value of these discussions, and the keenness of the delegates to take part in them was one of the most striking features of the Conference. The time was limited, and in every case the discussion had unfortunately to be cut short, while there were still numerous speakers wishing to be heard. The fact that so many important municipalities sent delegates, and that these delegates showed such a keen and intelligent interest in the possibility of the methods of preventing smoke, is considered most encouraging. In our opinion it is very largely to the

energy and zeal of local authorities that we must look for any improvement in the state of the atmosphere of our large cities, and it is hoped that the proceedings of this Conference may be of some value to such authorities in indicating to them the views of experts, on the one hand as to the possibility of abating smoke, and on the other hand as to the best methods by which this abatement can be achieved.

The draft Parliamentary Bill is printed as submitted to the Conference. The introductory remarks of the Chairman, and the subsequent discussion which took place, indicate fairly clearly the general consensus of opinion on this Bill. It was finally unanimously decided that the Bill should be referred back to the Executive Committee for further consideration, and that the Executive Committee should have the power to co-opt any persons of special knowledge to help them in this task. The revised Bill will then be submitted to the next Conference.

It was suggested that the next Conference should be held in London in the spring of next year, during the time when the International Smoke Abatement Exhibition, which is being organised by the London Coal Smoke Abatement Society, will be open.

It may be mentioned here that municipalities can become affiliated to the Smoke Abatement League upon payment of an affiliation fee of one guinea. This sum entitles the affiliated Branch to receive any publications which the League may make during the year, as well as to appoint two members to the Council of the League and so exercise a share in its management.

The League is also anxious to enroll as members as many persons as possible who are interested in Smoke Abatement. The minimum annual subscription for individuals is 2s. 6d., which makes the subscriber a member of the League and entitles him to receive all its publications. Forms of application for membership are obtainable from the Honorary Secretary, Mr. E. D. Simon.

ADDRESS BY THE LORD MAYOR OF MANCHESTER.

The meetings were held in the Lord Mayor's Parlour in the Town Hall, and were opened by the LORD MAYOR of MANCHESTER, who welcomed the delegates in a sympathetic speech.

After referring to the importance of the subject under discussion, and the representative character of the present gathering, the Lord Mayor proceeded to emphasize the suitability of Manchester as a centre for the Conference. Manchester was the great industrial centre of the world ; and so far as manufacturing was concerned, he did not think they would find any other place or centre with anything approaching the populaton and the industries that were carried on there. It was not only the cotton industry ; they had engineering and many other industries besides. Manchester had taken considerable interest in smoke abatement, and had put in free, not only gas cookers, but also heaters. This was a step in the right direction.

But the smoke problem was not to be solved by such things as these alone. The problem would only be solved by the economical production of gas and electricity, and when he said that he believed gas could be produced and put into the holders in Manchester at something under 1s. per thousand cubic feet, that made it possible for the question of the price of sale to be reviewed.

Perhaps he ought not to enter closely into these questions, but he thought it would be wise on the part of the Gas Committee to review the whole subject and see what could be done in the way of selling gas for heating and cooking purposes at a less price than it was sold at for lighting. He had no doubt that Principal Graham and others would put the health question before the Conference. With that aspect of the matter he was in entire sympathy, and he believed it could only be dealt with by gas being sold at a price which would attract people and cause them to use it in place of coal.

PRESIDENTIAL ADDRESS BY MR. GORDON HARVEY, M.P.

Mr. Gordon Harvey, M.P., delivered the presidential address. "We are here," Mr. Harvey said, "to advocate the urgent necessity of taking more active steps than have hitherto been attempted for the removal from the atmosphere of the defilements of unnecessary smoke and dirt. Some of us have been giving time and attention to this matter for many years with very partial success and under much discouragement; but I think that we may venture to congratulate ourselves on the fact that there are at last signs that public attention has been arrested. A short time ago anyone who protested against the clouds of darkness that hang over our towns and industrial districts was at once proclaimed a faddist, an enemy to commercial development, an altogether impracticable and meddlesome person. A sooty atmosphere had become identified with prosperity and booming trade. Smoking chimneys and plenty of them were the outward and visible signs of the inward and spiritual grace of fat dividends and regular wages. Some of us have conducted a long crusade against these notions, and my congratulatory message is that I think we are now storming the citadel. In innumerable cases it is now acknowledged that smoke can be entirely stopped.

"I am here to state as a manufacturer and dyer that this can be done where three conditions prevail—the first, adequate boiler room; the second, proper appliances for stoking and draught regulation; the third, by that careful watching of the boiler plant that is given to every other machine in every other part of the works. Moreover, it can be done on paying lines.

"There is another influence working strongly in our favour. There are signs everywhere of a remarkable and most laudable desire to improve the surroundings and conditions of the homes of the people. Garden cities are growing up; allotments are being provided; town planning and housing are in an Act of Parliament. The refinements of life are objects of greater desire everywhere, and it is beginning to be understood that it is a bad thing socially that people of means and education should be driven from the locality where workpeople are forced to dwell, and that barriers between classes should be carelessly erected by preventible causes. If we once get the economist and the social reformer working together the battle is won.

"This Conference is one of men from many places, where most varied conditions of trade, natural surroundings, and atmospheric conditions prevail, but I take it upon myself to

say that for no part of the whole kingdom is improvement more necessary than for South Lancashire. Nowhere are the towns so thick together or the smoke-making industries so numerous; but beyond this I may say that I know of no district where atmospheric conditions are so well adapted to make black smoke an intolerable nuisance. The prevailing moisture of the air (mugginess I believe unfriendly visitors call it) seems to absorb the smoke and brings it down in spots of inky, slimy rain.

"Let me in passing call attention to the pernicious effect of railway smoke, which, being mixed with steam, seems perhaps more harmful than smoke in any other form, and let me express the hope that special attention may be given to some endeavour to promote improvement on the railways and at the stations and yards. We shall not, I hope, neglect the grave question of domestic smoke. For improvements here we must and can reasonably look to the large substitution of gas for coal as an agency for heating and cooking. It will be a long time before you can substitute in homes the cheerful open fire by pipes and stoves; and, indeed, from the side of ventilation, the fire does perform its work, though in a wasteful way. But in a city of warehouses and shops influences which we may call sentimental do not prevail, and a heating range coupled with electric-fan ventilation should perform all the offices of the smoky open fire.

"Public sentiment is coming round, and science has come to our aid, and we want to hasten the pace of improvement. We propose to do that partly by legislation. I may be allowed to say that to my mind one of the most valuable provisions of the draft Bill is that which allows the creation of wide areas for the purpose of smoke observation and prevention. How powerless a small local authority is to check a nuisance where the members—the councillors—are often men who stand in awe of and are more or less dependent on people who produce it; and how unhappy is the fate of any place, however well intentioned, which is the dumping ground for the smoke and smuts of a rich and powerful neighbour.

"In promoting legislation we have reason to believe that we have the sympathy of the very able and practical statesman who presides at the Local Government Board. We have been assured by him that the end we have in view enlists his warmest sympathies. An attempt to legislate has also this great advantage—it brings the question prominently and in concrete form before all the parties concerned."

THE WORK AND POLICY OF THE SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN.

By E. D. SIMON, Esq. M.I.M.E., A.M.I.C.E.

My task this afternoon is a somewhat difficult one—to explain in a quarter of an hour why the Smoke Abatement League of Great Britain exists, what its objects are, and how it proposes to work towards them. First of all, I want to lay as much stress as I can upon one fact. The man in the street recognises that smoke is a bad thing, but with true British stolidity, he regards it as inevitable. When he hears of a Smoke Abatement League, he immediately puts the members down as a set of faddists. Our contention is that we are nothing of the kind. On the contrary, it is to the lack of imagination and enterprise on the part of the public that we owe the horrible state of the atmosphere of our great cities.

We know perfectly well that smoke cannot be abolished completely in the present generation. We know equally well that the quantity of smoke can be immensely reduced, and can be reduced without imposing any undue burden on manufacturers or others.

The Executive Committee of the Smoke Abatement League consists almost entirely of practical men. If further evidence of the saneness and practical character of our aims is required, it may be found in the fact that we are supported both by subscriptions and by the presence here to-day of delegates of such great municipalities as Glasgow, Liverpool, Birmingham, Belfast, Leeds, and many others.

That a smoky atmosphere is a noxious and unpleasant thing is admitted by all, but the extent of the evil is not generally recognised, and I propose to give quite shortly one or two facts in connection with Manchester smoke, which I think may help to bring the matter home.

The Municipal Technical School affords a good indication of the amount of dirt that enters our buildings. The Corporation have installed a plant for washing soot out of the air which is introduced into the school. At frequent intervals, men have actually to go in with spades to dig out the accumulated filth which, but for this washing plant, would have penetrated into the interior of the school. On one foggy day recently, no less than 1 cwt. of black sludge was filtered out in 14 hours, that is, at the rate of nearly 10lbs. an hour; and even so, a good deal of dirt gets into the building.

It is extremely difficult to estimate the damage done to clothes, curtains, carpets, and so forth, but some idea of the magnitude of the sum involved may be obtained by considering the extra cost of washing collars owing to smoke. In Manchester it is hardly possible to wear a collar more than one day; in the country it can be easily worn two or three days. The charge for washing a collar is a penny, so that assuming one extra collar to be required every second day, the cost in this item alone—of living in Manchester—may be taken at ½d. per head per day. I do not know what proportion of the population wear reasonably clean collars, but taking it only at one-twenty-fourth, which I think is certainly low enough, the extra cost of washing the Manchester and Salford collars, owing to the smokiness of the atmosphere, comes out at no less than £30,000 each year.

This is bad enough, but the really serious damage done by smoke is to health. It is a well-known fact that if the lungs of anybody living in an ordinary smoky town be examined, they will be found to be coated with a perfectly black deposit; and the black deposit obtained from the Manchester atmosphere is not pure carbon, which would be comparatively harmless, but contains tarry matters and sulphurous and sulphuric acids and all sorts of undesirable chemicals. The expectation that this is bound to affect health is amply confirmed by evidence.

As regards Manchester this is clearly proved in Dr. Niven's interesting paper published in the catalogue of the Smoke Abatement Exhibition.

Many attempts have been made to estimate in cash the total damage done by smoke. Three separate estimates, made in London, Manchester, and Glasgow respectively, agree that £1 per head of the population per annum is a low figure for any of these cities. The most carefully worked out of these estimates was made by the Hon. Rollo Russell, for London. In the figure of about £5,000,000 at which he finally arrived as the amount

of damage done by smoke, he included £320,000 as damage done to health. It is not quite clear how he arrived at this latter figure, which is equivalent to about 1s. 6d. per head of the population per annum, but I think it will be agreed that this figure at least is estimated on a very conservative basis.

Once people realise the extent of this damage, I feel sure that an insistent demand will arise that it shall be reduced in some way. The business of the Smoke Abatement League of Great Britain is to persuade the public that it is a perfectly practicable proposition to purify the atmosphere of our large towns, and that the means of doing this are now well known.

In considering shortly what these means are, we must differentiate between the smoke from factory chimneys and from private houses.

Dealing first with the former, the papers we are to hear to-morrow by two practical engineers go far to prove that factory smoke can be almost entirely prevented, except under quite abnormal conditions.

There are three lines of attack against factory smoke :—

(1) To help energetic and progressive local authorities, such as Manchester, in their efforts to suppress smoke, by pressing for new legislation giving them wider powers.

(2) To bring pressure to bear upon backward authorities, and to endeavour to bring them up to the level of the best.

(3) And most important is the replacement of ordinary furnaces burning bituminous coal by electric or gas power.

The gas engine is rapidly becoming a more reliable and economical means of producing power, and it has the great advantage not only of being smokeless, but of preventing the emission into the atmosphere of, at any rate, the largest proportion of the sulphurous acid which is produced whenever coal and coke are burnt.

Excellent work has for many years been done by the London Coal Smoke Abatement Society, who employ a private Smoke Inspector of their own, and have been very successful in stimulating the London boroughs to action. They have a map showing many hundreds of chimneys which, before the Society began its labours, were constantly emitting black smoke, but about which no complaints can now be made.

One of the objects of the League must be to found energetic branches in the smokier centres, and to follow the example of London in this matter. I may say that it is hoped that a branch

for Manchester and district will be started on these lines in the course of the next few weeks.

I have left the domestic chimney to the last, and I admit at once that it is the most difficult part of our problem. It is domestic smoke which does the greatest amount of damage, and to attempt to induce the British public to abjure the use of the open coal fire is a task that may well appal the boldest reformer. It is generally agreed that something like 5 per cent. of the coal burnt in the open fire passes up the chimney in the form of smoke. It is estimated that about 700,000 tons of coal per annum are burnt in this way in Manchester, the result being that no less than 35,000 tons of soot are poured into the Manchester atmosphere every year.

We have heard a good deal lately about smokeless fuels to replace ordinary coal, but hitherto nobody has been able to produce a smokeless fuel on a large scale at a low enough price to enable it to compete with coal. Many people are still experimenting on the subject. There is no doubt that this would be by far the best solution of the problem, and we can only fervently hope that success may attend their efforts.

The use of smokeless anthracite and coke stoves, which have the merit of being an extremely cheap form of heating, is also a move in the right direction. Electric heaters are, of course, absolutely clean, but unfortunately are still very expensive.

The immediately practical way of tackling the domestic smoke problem is by an extension of the use of gas for cooking and heating.

There is still a strong prejudice against gas fires to be overcome. The belief is commonly held that a gas fire means an unduly dry atmosphere and a stuffy room. Both beliefs are utterly fallacious as regards the modern gas fire, and are due to the results of the inferior stoves formerly sold. Anyone who has seen the latest type of gas stove at work will admit that the atmosphere of the room is just as good as when an open coal fire is used, and some of the latest and best gas fires are really almost as attractive even to look at and to sit beside as a coal fire.

Of course we do not propose to ask people to give up the open fire entirely and immediately. The gas fire has only just become sufficiently healthy and attractive to replace the coal fire with advantage in a sitting room, and even now, it is in most towns more expensive than a coal fire for continuous use. On the other hand, for cooking, for bedrooms, and for dressing-

rooms; in fact, wherever the fire is not in continuous use for the whole of the day, the gas fire is not only cleaner, but cheaper and much more convenient than the coal fire. If only everybody could be induced to use gas fires except in sitting-rooms, the domestic smoke problem would be, to a large extent, solved.

The Manchester Corporation is, in many ways, most progressive, but in regard to the one question of gas, I am sorry to say that their action leaves much to be desired. They sell gas at 2s. 3d. per 1,000 cubic feet. This price includes a profit of 2d. and a direct contribution of 2d. to the rates. Now, the extended use of gas is the one way of cleansing our city. The reduction in the price of gas is the only way to accelerate this extended use. If the Corporation would forego the profit of £50,000 a year which they make on gas, they would be going a long way towards doing away with the loss of at least £700,000 a year which is caused by smoke. The ratepayer is apt to put actual reduction of the rates before anything else, but surely it will pay every ratepayer over and over again to forego this contribution from the Gas Committee, in an honest endeavour to render Manchester a city fit for rational human beings to live in.

I may say, incidentally, that a special Committee of the Manchester City Council is at present considering the price of gas and electricity, and I sincerely hope that many of its members will listen to the papers which will be read this evening and to-morrow morning, and will attend the next meeting of their committee with a firm determination that the tax on Manchester gas shall be removed, or, at least, very considerably reduced.

We smoke abaters are frequently told that if we want to do any good in the world the first thing to do is to give up smoke abatement and take up something more practicable. The fallacy of the underlying assumption that smoke abatement is a quite impracticable ideal is best shown by what has already been done in Manchester.

Notwithstanding the high price of gas over 50,000 gas cookers have been installed in the last eight years. The Gas Committee has now agreed to fix gas fires free, and the demand for them is most gratifying. The gas consumed during the last financial year for power, heating, and cooking, is officially estimated to be equivalent to over 50,000 tons of coal; that is to say, that owing to the use of gas for these purposes something like 2,000 tons less soot was discharged into the Manchester atmosphere last year than would otherwise have been the case.

In addition to this, some improvement has been made by the use of electricity for power, and a good deal has been done in rendering factory chimneys more smokeless. There can be no doubt whatever that but for these efforts the state of the atmosphere would be much worse than it is. In fact, notwithstanding the increase in the population, Dr. Niven's paper shows that the fogs in Manchester have considerably decreased during the last ten years.

To come now to the actual work of our League, generally speaking the work of the Central Committee should consist mainly in the establishment of branches, collection and dissemination of information, the organisation of conferences, and the improvement of legislation. If funds permit we might emulate Germany by the establishment of a monthly magazine devoted to the question of smoke abatement. Branches should be established in all the smokier districts and should employ private smoke inspectors, arrange for lectures of all kinds, the holding of exhibitions, and do what they can to induce local authorities to encourage the use of gas and electricity.

There are four main lines of action which at the present moment I should put in the following order of importance :—

(1) To educate public opinion as to the urgency and practicability of smoke abatement.

(2) To endeavour in all ways to increase the consumption of gas and electricity for power, heating, and cooking.

(3) To stimulate the activities of local authorities with regard to factory chimneys by the employment of private smoke inspectors.

(4) To forward any reforms of legislation that are likely to render the efforts of local authorities more effective.

We believe that public opinion is now ripe for a serious and, we hope, a unanimous attempt to grapple with this problem. One of the most favourable signs is the very friendly way in which our various communications have been received by many of the great Municipal Corporations. Numbers of them have shown themselves ready to give us any information, to affiliate themselves to our League (which is almost unknown, and still in a somewhat undeveloped state), and to send delegates to our Conference to-day. Everybody agrees that something ought to be done, but hitherto this feeling has not been organised or converted into action. We have investigated the whole matter carefully and now lay before the public a definite, simple, and practical programme. We realise that it is quite impossible

to do away with smoke completely, but the great point is that a small amount of smoke does not matter. It is only when excessive quantities are emitted in a relatively small area that real damage is done. We are convinced that immense improvements could be made in all our large manufacturing towns.

We have not yet made any public appeal for money, but in order to organise and direct into the right channels the latent energy which is available for our purpose, funds are necessary. We confidently appeal for subscriptions to enable us to carry on a vigorous campaign, and if not to abolish, at least very much to reduce the quantity of smoke and other impurities in the atmosphere of our large cities.

In conclusion, let me state again that we do not wish to burden industry by irksome laws against smoke. We wish to prove to the manufacturer that smokeless chimneys are more economical than smoky ones. We wish to prove to the householder that smokeless fires are cheaper, and pleasanter, and healthier than smoky fires. Wherever and whenever possible gas and electricity should be supplied in our large industrial towns cheaply enough to be used for all purposes, industrial as well as domestic. That is the ideal towards which our League strives, and in view of the active sympathy which is now being shown by so many local authorities we are confident that our progress towards this ideal will from now on be very much more rapid than it has been in the past.

"LET THERE BE LIGHT."

By Dr. DES VŒUX.

A summer holiday spent in the highlands of Scotland may lead to reflections on events past and present which could not have been a priori anticipated. A somewhat lonely, very hilly glen, with beautiful views of mountain, moor, and dale, seems distant in atmosphere, both mental and physical, from the fogs of towns. But this glen, which now boasts of but three shooting-lodges and as many farmhouses, was once fairly densely populated by farmers and crofters, who scratched from the inhospitable soil a small and precarious living. Modern civilisation has ordained that these lovely glens shall be deserted, that the whilom inhabitants shall spend their lives in the meaner surroundings of towns. On a still beautiful September day, when sitting on the top of one of these mountains, admiring the landscape near and far, in several separate spots I saw hanging above the earth (or was it suspended from heaven ?) a black cloud, as if there were a thunderstorm breaking out in half-a-dozen places at the same time. On close watching of these clouds, I noticed they neither moved or enlarged, and on fixing their earth relationship I found that each cloud was suspended above a town—Dundee, Montrose, Forfar, and Kirriemuir, and one or two others—and that, in fact, "the clouds" were the dots above the "i's" of our boasted civilisation. It seems unfortunate that one has to go to the mountains of Scotland to see these dots. But in our dismal town surroundings our eyesight is too blurred. We spend the greater part of our lives embedded in them, and habit has so accustomed us to their nature, that it excites little interest amongst us, and certainly no sense of rebellion against its demoniacal structure. And what are these monstrous dots ? What are they composed of ? and whence do they come ? We all know, if we but think—they are the vast accumulations of the outpourings of the chimneys, a huge aggregation of tar-laden smuts, poisonous acids, and noxious fumes which hang all day long, from year's end to year's end, only varying in intensity

according to the state of the weather. Unheeded by our rulers, imperial or civic, they have lain there for centuries, black or brown, invading our homes, destroying our property, injuring our health, devitalising the young, and destroying the old.

And what do we call this thing ? Fog ; we might just as well call it rain. True, fog and rain each in their own way have an effect upon the smoke—in times of fog, the smoke is prevented from escape from its surroundings ; it therefore intensifies, thickens, and dirties fog—in times of rain, the latter brings down the smoke with it to the earth, and it therefore purifies and cleans the previously dirty air. This thing may be called "smog," if a name is wanted to show that it is compounded of smoke and fog, but to call it fog is an insult to heaven. I have said above that this black fiend is ever present in more or less degree, and you may ask what proof I have of this. There is the proof of smell, of taste, of touch, and sight, and perhaps more convincing to the sceptic the tell-tale truth of the automatic sunshine recorders. These show that our loss of sunshine in London varies from 15 per cent. in summer to 50 per cent. in winter ; or, in other words, that the pall of smoke absolutely prevents the sun for a percentage of the time it is above the horizon from shining on us. In this great city of Manchester, notorious from one end of the world to the other for its business and its cottons, there is one thing of which you cannot boast, your records of sunshine. I notice that a few days ago an eminent professor of Sheffield enunciated the aphorism "No smoke, no steel." Where is the Manchester professor who will say "No smoke, no cotton" ? Is it necessary for me to bring proof of the other charges against smoke ? Suffice it, on this occasion, to say that a calculation that smoke, directly and indirectly, costs London £5,000,000 per annum has never been refuted, or even disputed, and that therefore a sum which is wasted by smoke in the Metropolis alone every year could in under a century pay off the National Debt of the United Kingdom.

That smoke blackens the stone and brick of our houses is evident to the blindest eye, but that it actually destroys stone work is not so well known. But in London we have ample evidence of it. To mention only two instances—St. Paul's Cathedral and Westminster Abbey, which are not only of Metropolitan but Imperial, and may I say of Greater-Imperial, interest. You have all, or most of you, visited Oxford, where you find a greater aggregation of beautiful architecture than perhaps in any city in the world. Beyond the beauty, look at the destruction ;

you will see in nearly all the Colleges in its typical form the mischief wrought by smoke on stone. First the blackness, then the raising of a blister-like mass, then the crumbling or breaking off of the blister shell, leaving what we in surgery would call an ulcerated, ragged surface beneath ; and what is being done for this ? You would think that in a centre of learning and great antiquarian interest that the damage would be dealt with in a broad and statesmanlike manner, that the cause would be sought, and when found, if possible, prevented. Not at all ; we find college after college in the hands of the repairing architect and builder, thousands being spent annually by individual colleges and the University itself (for the college buildings are under separate authority from the University buildings), and no effort being made to get rid of the smoke, mostly probably manufactured in the college premises whose destruction it is causing. If these two great charges are true, that is, the enormous annual cost, and the destruction of ancient national monumental buildings, it is hardly necessary for me to weary you with much more evidence, but being a medical man, I cannot refrain from giving you some figures of mortality collected from your sister sufferer, Glasgow. In the autumn of 1909 Glasgow was visited by two periods of smoke fog, each lasting several days, but separated by an interval of a few weeks. During the first period the death rate suddenly rose from 18 per thousand to 25 per thousand, and during the second to 33 per thousand, although the rate in the surrounding country was hardly raised. It was calculated that 1,063 deaths were attributable to the noxious condition of the atmosphere. These terrible facts passed almost unnoticed, yet only 10 years previously, when about 1,000 soldiers were killed and wounded in a week in South Africa, the week was called "The Black Week," and many thought that to continue the war would be useless. The horrors of that South African week were depicted in every newspaper in the kingdom, and the effect produced was the gloomiest that I have ever known. But the Glasgow figures given above are only a corroboration of statistics of death from similar visitations elsewhere, such, for instance, as those from a great fog in London in 1880 which caused over 2,900 deaths, more in fact than were lost in action in the first year of the war in South Africa. Familiarity, in fact, as usual, breeds contempt. We are so accustomed to the evils of smoke that we take no notice of them, and these vital statistics are so seldom commented on that they might be to all intents and purposes non-existent.

I take it that we are now all agreed that, if it is possible to

get rid of smoke, the case against it is very strong. Can we get rid of it ? I emphatically say that we can if we try ; but are we ready to try ? The answer to that is doubtful. Take it as a whole, the people of these isles are still hostile or apathetic, but not so much so as 15 years ago, when I first began seriously to consider the question. The attitude has changed and is still changing. I was first met with ridicule and contempt, and for years no converts were made, but when I read that Mahomet only gained 13 followers in three years, I do not think that we need be downhearted on the results that have followed. The Coal Smoke Abatement Society was formed just 12 years ago, to start out on a weary, lonesome task of preaching, teaching, and experiment. We were tabooed by the manufacturer because we should "touch his pocket" ;—"drive away trade," was his euphemistic expression for it—and tabooed by the householder because we should take away the fire which he could poke. Our first great friends and our first great encouragers were the County Council of London—more honour to them, and "more power to their elbow," as is said across the water. If it had not been for the London County Council we might have fallen by the way and perished out of sight. And now what do we see ? Interest arising—perhaps in small degree, and perhaps as yet doing little good, but still arising and bestirring itself, slowly and deliberately, opening its eye, awakening to the evil, and trying to discover the truth between the statements of the manufacturers on the one side and the "faddist" on the other. That we are faddists is not deniable, but that we are faddists in the hurtful and malign sense I deny with all the force that is in me. The manufacturers say we are faddists because we only think of the smoke and not of the trade. This is absolutely untrue of the Coal Smoke Abatement Society. There is not a member of the Council of that Society who is not open to reasonable argument ; but we all deny that the simple expression of a law-breaking manufacturer is to be taken as proof of injury as against the manifold proofs which we have accumulated and which show that no injury is caused by abatement of smoke. One point is of great significance and importance ; it is always the manufacturer who has not mended his ways who complains of our driving away trade, and the threat is always of the future—"The works will have to close," "The trade will go." There has never been an attempt to prove that any single manufactory of any size, sort, or description has ever been closed through increase of expense owing to abatement of smoke, or any other reason in connection

with abatement of smoke. And yet it is a fact that in the London area 913 factories of all sorts which formerly emitted smoke "in such quantity as to be a nuisance" have in the last 10 years ceased to do so. The success of the London society has naturally stimulated action in other places, and the Smoke Abatement League is bravely carrying the "faddish" flag into the enemies' quarters, and I here assert that our enthusiasm for a decently clean atmosphere is not going to be cooled by opprobrious epithets on the part of opponents. Fair argument and scientific proof we are open to; but abuse is the sign of a bad attorney or a bad cause. It is asserted that it is useless to attack the manufacturer's smoke and leave the householder alone, and now the manufacturer has a new weapon, that "the smoke from a domestic chimney is more harmful than that from a manufacturer's." This is apparently true, and no one who is on our side wants to burke the domestic question, but there is this great difference between the two—thirty years ago Parliament in its wisdom passed an Act that made smoke issuing from chimneys, other than domestic chimneys, illegal. We cannot go beyond this Act, but we have been doing our best to minimise the evil—enormous as it is—of smoke from the domestic hearth. We have tested grates, stoves, fuels, solid and gaseous, and done everything we could do to draw attention to the evil. Exhibitions have been held in London (twice), in Sheffield, Glasgow, and now in Manchester, and in March next we are hoping to have a great exhibition again in London. A large part of all of these exhibitions has been given up to the domestic problem; and in London alone the decrease of fires using dirty bituminous coal is prodigious. The last great stage in the final settlement of this part of the question will be the invention of a solid, smokeless fuel. That this is only a matter of time I have no doubt. A good many of these fuels have been put on the market so far which give out a powerful radiant heat, are clean in working, and in most ways satisfactory, but for one reason or another they have not yet given complete satisfaction, principally, I think, because they are not quite fit for the ordinary type of kitchen range; but I have no doubt before long the difficulties will be cleared up, for in the last month my attention has been drawn to three new solid smokeless fuels, showing that a demand for it exists, and if the demand exists the supply will surely follow. With gas and electricity striving against each other in rivalry for the customer, with anthracite coal, and central heating, not to speak of coke,

each taking a place in the economy of the house, who can say that the domestic problem is untouched.

I fear I have trespassed long on your patience, and that you may say of my paper it is discursive and unsatisfactory—I feel it is so—and that if I had limited myself to one branch of the subject, my remarks might have been of more use, but I thought as this meeting is not a sectional meeting but a general meeting that a rapid touching on some of the many problems that arise in a big reform of this sort would at any rate stimulate reflection and, I hope, criticism. Discussion is what we invite, anything rather than apathy. The world is alive now with social problems, and this is one of them, and I cannot help thinking if the atmosphere of our cities was assimilated, as by Nature it is, to the atmosphere of our Scottish hills, that many poor-law problems would settle themselves. Dirt and darkness are the twin children of smoke, and to them are closely related poverty, drunkenness, and crime.

DISCUSSION ON THE WORK OF THE LEAGUE.

The Chairman (Mr. Harvey), in inviting discussion on the papers read, intimated that observations on legislative proposals should be avoided, as there would be a full opportunity for such discussion afterwards.

Mr. T. C. Horsfall (Manchester) wished to say a word about the policy followed in Manchester of charging a price for gas which enabled the Gas Committee to make a large contribution towards the rates. He said that we were living in a country in which—as was the case in no other country—78 per cent. of the people were living in large towns, where the conditions were certainly not favourable to health. He knew that the population of this country was now in a state of absolutely unparalleled physical deterioration. In Manchester, in 1899, of 11,000 men who wanted to enlist, only 9 per cent. were found to be physically fit for regiments of the line. And at the present moment the Navy could only accept 14 per cent. of the boys belonging to all grades of society who wanted to join. He said fearlessly that there were no figures among the races of the world comparable with these in their revelation of physical deterioration. With these facts before him, he asked : By whom were we ruled ? Was it by men who were sane when they hesitated to sacrifice

£50,000 for a change that unquestionably would lead to a very marked improvement in the conditions under which the mass of our people had to live? Let us clear the air, he said, and make it possible for orderly and sensible housewives to open their windows and ventilate their rooms. We should then have an improvement which would unquestionably be worth not £50,000 or £500,000 a year, but an improvement which could not be stated in terms of money. The point seemed to him so all-important that this change—the most practicable that had to do with the question of smoke abatement—should be made at once.

Mr. MARSH (Manchester) said that there could be no doubt that our manufacturers had done wonders in the way of using coal in a proper and economical manner, and he held that the great bulk of the smoke in our cities was smoke from domestic chimneys. The smoke from the factory chimney was not the smoke that stuck upon our buildings. The only real method of doing away with the smoke nuisance was one that was proposed by the late Professor Symons—gaseous fuel. How were we to get this gaseous fuel? It was in the hands of our town councils to give it. Our corporations should give us the opportunity of having gas at a price at which we could afford to use it as fuel, and he hoped the Conference would express the opinion that corporations, instead of handing over a large amount of money to be expended in other directions, would give us gas without profit, or almost without it.

Dr. BROWN (Medical Officer of Health for Bacup, Lancashire) said that if the Local Government Board had taken the hint which he had given them, in the last ten years we should have had in South-east Lancashire hundreds more people alive and well to-day. Our death rate in South-east Lancashire from respiratory diseases was very considerably more than in the south and western parts of the country. And that was simply because we breathed filth—all the year round—and desperate doses of it from November until March. We breathed it into our lungs which did not get the oxygen they ought to get. This question had not aroused the sanitary authorities of South-east Lancashire as it should have done. Gas ought to be sold at 1s. 6d. per 1,000 cubic feet for domestic purposes. (Hear, hear.) In Manchester there was no excuse for the present charge. It was a disgrace to Manchester that it should make £50,000 a year, and have its people breathing more filth than they had need to. They had only to take up the health reports of medical officers and compare them with Manchester's to see that they

were wasting life, and wasting the happiness of our homes. He hoped that in South-east Lancashire the corporations would recognise that the domestic chimney was a wasteful method of getting heat.

Several other delegates took part in the discussion, mostly laying special stress on the paramount importance of cheap gas.

SPEECH BY PRINCIPAL J. W. GRAHAM, M.A.,

EXPLAINING THE DRAFT PARLIAMENTARY BILL.

Mr. Graham said that a preliminary draft of the Bill was submitted to a large number of municipalities, and that in its present form it was largely based on suggestions from them. Mr. Graham then proceeded to explain those clauses of the Bill in which it differed substantially from former Bills, and to point out the reasons for those alterations : " With regard to Clause 1, Section 1, I should like to remind the Conference how difficult the enforcement of the law has been made by such phrases as 'black smoke,' 'smoke such as to cause a nuisance,' 'the consumption of smoke as far as practicable.' All such phrases have led to evasions of the law on points of fact. I therefore suggest, personally, that the draft Bill should be modified so as to require 'that fireplaces or furnaces shall consume their own smoke,' it being left to the good sense of smoke inspectors not to prosecute in cases of breakdown of machinery, or other such unavoidable accidents. I also suggest that the law might fairly be enforced in all strictness against those who fail to make their furnaces consume their own smoke, for it is now open to almost all industrial undertakings to minimise their smoke : (1) by the use of smokeless fuels ; (2) by the use of mechanical stokers, hot blasts, and regulated draughts ; (3) by the passing of any smoke generated through special smoke-consuming furnaces or appliances."

In the case of metallurgical and pottery works, Mr. Graham said that it was true that smoke could not for the present be avoided. Accordingly, he proposed that the Local Government Board should have powers given them to exempt furnaces in such works, on appeal, from the operation of the proposed Act, for a space of one year at a time.

The delegation of these powers to skilled officials under the Local Government Board would, he held, make the decisions in such cases more uniform instead of leaving them at the mercy of the varying and sometimes biassed judgments of local magistrates.

Passing on to Clause III., Mr. Graham criticised the local administration of existing Smoke Acts in many parts of the country: "The chief defect in administration lies in the fact that the local authorities usually do not cover a large enough area to enable them to deal effectively with the nuisance of smoke."

He proceeded to outline the creation by the Local Government Board, provided for in this Bill, of local smoke authorities covering wider areas than the present ones, such authorities to consist of representatives from the local town and district authorities concerned. The Local Government Board was also to employ National Inspectors to report on the work of these local authorities. Thus, he believed, under the stimulus of skilled central criticism, public spirit would be encouraged, and lethargy compelled to obey the law throughout the country.

Mr. Graham concluded by saying that the Bill presented to the Conference must not be taken as being in its final form. Criticism was welcomed to aid in that clear understanding of these problems which must be the prelude to their satisfactory solution; problems of vast and far-reaching national importance which the League was approaching in no irresponsible spirit.

DRAFT OF SMOKE PREVENTION ACT, 1912.

Be it enacted by the King's Most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal and Commons in this present Parliament assembled and by the authority of the same as follows:—

Duties of persons employing furnaces.

1.—(1) Every furnace employed or to be employed in the working of engines by steam and every furnace employed or to be employed in any mill factory printing house dye-house glass-house distillery brewhouse sugar refinery bakers gasworks waterworks or other buildings used for the purpose of trade or manufacture (although a steam engine be not used or employed therein) including the engines or furnaces of any steam vessel on or plying on the territorial waters of his Majesty shall in all cases be constructed or altered upon the principle of consuming and so as to consume or burn the smoke arising from such furnace.

(2) The provisions of this section shall extend to and be applicable in respect of the emission from any chimney in connection with any such furnace of any grit or gritty particles.

(3) The words "consume or burn the smoke" in this section shall be held in all cases, save as in this Act expressly provided to consume or burn all the smoke and any provision to the contrary notwithstanding the court hearing an information against a person shall not fail to make any order or remit any fine unless such person can show that he has not been guilty of any negligence or omission in satisfying the requirements of this Act or that the emission was due to an accident or other cause which such person could not reasonably have been expected to have foreseen or prevented.

Offences.

2.—(1) If any person uses or suffers to be used any such furnace which shall not be constructed upon the principle of consuming and so as to consume or burn its own smoke, or if any person using or permitting to be used any furnace so constructed shall in the event of the smoke arising therefrom not being effectively consumed or burnt or in the event of grit or gritty particles being emitted from such furnace, fail to show, as in section one sub-section three of this Act provided, that such furnace has not been negligently used, he shall if he is the owner or occupier of the premises or a foreman or other person employed by such owner or occupier be liable to a fine not exceeding five pounds, and on a second conviction to a fine not exceeding ten pounds and on every subsequent conviction to a fine not exceeding twice the amount of the maximum fine last inflicted.

(2) Provided that, if an interval of two years elapse between any one conviction and the next, such person shall not be liable to a greater fine than on the occasion of the conviction next preceding it. Provided further that in no event shall a fine exceeding £50 be inflicted on the occasion of any conviction.

(3) No person shall be prosecuted or otherwise proceeded against for an offence under this Act unless he is notified of the intended prosecution or other proceeding within twenty-four hours (excluding Sundays) from the commission of the offence.

(4) Any person who, having been prosecuted and convicted of an offence under this Act, shall continue after such conviction to offend against the provisions of this Act shall be further liable to a fine not exceeding five pounds for every day during which such offence is committed, in addition to any other penalties imposed by this or any other Act.

(5) Save as in this Act expressly provided all prosecutions under this Act shall be in such form and manner and before such court as is provided in the case of prosecutions for nuisances under the Public Health Act 1875, and any other Act amending that Act, and the court shall have all the powers to make orders dealing with the abatement of offences or the execution of new works they have or any

other matter with which they are competent to deal with which they have under the Public Health Act 1875, or any other Act amending that Act.

(6) In the event of an offence under this Act within the district of a local Smoke Prevention authority appearing to be wholly or partially caused by some act or default committed or taking place without their district, the local Smoke Prevention authority shall exercise their powers and duties under this Act in like manner as a local authority may exercise its powers and duties with regard to nuisances under the Public Health Act 1875. 38 & 39 Vic. c 55.

(7) For the purpose of the provisions of this Act any ship or vessel lying in any river, harbour or other water within the territorial waters of his Majesty shall be subject to the jurisdiction of such local Smoke Prevention authority within whose district such river harbour or other water is or such territorial water of his Majesty is contiguous.

Powers and duties of local Smoke Prevention Authorities.

3.—(1) The Local Government Board, by provisional order, shall constitute local smoke prevention authorities, acting in the areas of such local authorities as the Local Government Board may deem fit, and the order may contain such provisions respecting the constitution and proceedings of such local smoke prevention authorities as may seem proper, and may provide for the payment of the expenses of such local smoke prevention authorities by the local authorities, within whose areas the smoke prevention authority may act and for the audit of the accounts of such local smoke prevention authorities and their officers.

(2) The London County Council, in London, shall have and exercise all the powers and duties of a local smoke prevention authority.

(3) It shall be the duty of every local smoke prevention authority to enforce the provisions of this Act.

Local authority to appoint local Smoke Inspectors.

4.—(1) Every local smoke prevention authority shall appoint from time to time fit and proper persons to be local smoke inspectors.

(2) The Local Government Board shall have the same powers with regard to the qualification, appointment, duties and salary and tenure of office of a local smoke inspector as they have with regard to any other officer of a local authority part of whose salary is paid out of moneys provided by Parliament.

(3) The local smoke inspector shall report to the local smoke prevention authority the existence of any smoke nuisance which in his opinion would constitute an offence under this or any other Act, and the local smoke prevention authority shall cause a book to be kept in which shall be entered all complaints made of any infringements of the provisions of this Act made hereunder and every such

inspector shall forthwith enquire into the truth or otherwise of such complaint and report upon the same, and such report shall be laid before the local smoke prevention authority at their next meeting. Any action thereon taken shall be forthwith reported to the Local Government Board.

(4) It shall be the duty of such local smoke inspector, subject to the direction of the local smoke prevention authority to take legal proceedings for the punishment of any person for any offence under the Act.

Powers and duties of local Government Board. Government Smoke Inspectors.

5.—(1) The Local Government Board shall have the right to inspect any such books recording offences and may, if in their opinion, the inspection or prosecution of offences under this Act has been negligently omitted, refuse to pay such part of the salary of local smoke inspectors as they are entitled to pay under this section as may seem to them just.

(2) Save as in this section provided, there shall be paid annually out of moneys provided, by Parliament, a sum which shall not exceed 10,000 pounds sterling, under regulations to be framed by the Local Government Board with the approval of the Treasury; and out of this sum the Local Government Board shall pay to every local smoke prevention authority a contribution not exceeding one-half of the salaries of local smoke inspectors towards defraying the expenses of such salaries.

(3) The Local Government Board shall, for the purpose of this Act, appoint such Government smoke inspectors, being persons of experience in the science of chemistry and engineering as they may think fit, acting in such areas as they may deem necessary, for the purpose of inspecting the operations of and stimulating the work of local smoke prevention authorities, and such Government smoke inspectors shall, at such times as the Local Government Board may prescribe, report upon the work of the local smoke prevention authorities, which reports shall be presented to Parliament by the Local Government Board at least once in every year.

(4) The Government inspectors shall have power in cases where in their opinion, an offence under this Act has been committed and the smoke prevention authority have failed to prosecute themselves to undertake such prosecution provided that the expenses of such prosecution if any, shall be paid by the local smoke prevention authority within whose area such offence was committed.

Allocation and payment of expenses.

6.—The expenses of a local smoke prevention authority shall be allocated by order of the Local Government Board among the various local authorities within whose area such local smoke prevention authority is authorised to act, and such expenses shall so far as not otherwise provided for, be paid, in the case of the council or a county out of a county fund, and in the case of the council of a borough or urban district out of such rate as is usually devoted to defraying the expenses of the Public Health Acts.

7.—In the application of this Act to Scotland, the expression "Local Government Board for Scotland" shall be substituted for "Local Government Board" and the expression "Public Health (Scotland) Act, 1897" for "Public Health Act, 1875." Application of Act to Scotland. Ireland and London. 60 & 61 Vic. c.38.

In the application of this Act to Ireland the expression "Local Government Board for Ireland" shall be substituted for "Local Government Board" and the expression "Public Health (Ireland) Act, 1878" for "Public Health Act, 1898." 41 & 42 Vic. c.52.

In the application of this Act to London, the expression "Public Health (London) Act, 1891" shall be substituted for "Public Health Act, 1875."

8.—This Act may be cited as the Smoke Prevention Act, 1912. Short title.

DISCUSSION ON THE DRAFT BILL.

Sir John Bingham (Sheffield) said that without promoting any Bill whatever it was possible to take action with regard to smoke nuisance under the Public Health Act of 1875, section 91, sub-section 7. His firm took action upon this Act 20 years ago in consequence of smoke coming into their factory and injuring the health of their people, and they won their case. Seeing that this was so it had seemed strange to him that the Act of 1875 had not been more generally utilised for prosecutions. He admired the intention of the proposed Bill, but there were points in it which he thought should be settled in Committee. (Hear, hear.) There was one point upon which he felt sure that the Bill could not pass as it stood. Whilst it spoke of the assistance of the Local Government Board it omitted a very vital point—the power that councils and manufacturers had over the smoke inspector. The great point should be to have the smoke inspectors appointed outside the municipality. The latter should have no power whatever over them. (Hear, hear.) They should be under the control of the Local Government Board. As to fines, wherever a man was convicted of wilfully making smoke there should be a fine which the magistrates should not have the power to minimise. There should be a proper fine, and the magistrates should have no power to reduce it but power to double it. (Applause.)

Mr. Watling (assistant solicitor to Bradford Corporation) said that as far as he gathered it was intended by the proposed

Bill to set up a separate authority for the purpose of dealing with smoke prevention. It proposed to set up an entirely different authority from the urban sanitary authority now existent in the various urban areas. With all due deference he thought this was rather a bad principle to perpetuate. Unfortunately to-day we had a multiplicity of local authorities. We had the municipal corporations; we had the Boards of Guardians; and we had the Distress Committees—three bodies dealing in different ways with various social matters affecting the community. To these the Bill proposed to add a fourth, and he gathered that the argument in its favour was that it would be a body which would not be controlled either by the manufacturer or anybody on the Council who had an axe to grind. A further argument would be that it would secure a consistent execution of the Act and a complete change of the methods in vogue to-day.

He thought that if clause III., sub-section 3, stood part of the Act—making it incumbent on every local smoke prevention authority to enforce the provisions of the Act—that would be sufficient for their purposes. He could not conceive that any separate authority could do more than many of our country boroughs were doing to-day. He felt sure—and the chairman of the Health Committee, who was present, would corroborate him—that they would, as municipal corporations, be forced to oppose them on this part of the Bill. They regarded it as an undemocratic principle to set up an authority to deal with public health other than the urban sanitary authorities which existed to-day.

Another point of principle to which he would draw their attention was the question of the status of the Local Government Board in the matter. He understood that the general principle they proposed to adopt was that the Local Government Board should have a supervisory control over the whole working of the Act. He was not quite sure whether that would be a pleasing feature so far as urban sanitary authorities were concerned. No doubt there were present there many members of local authorities. They would unfortunately realise only too strongly what was the attitude of the Local Government Board with regard to the various Acts they had to control when the local authorities approached them. It was also suggested that they should be the persons to control the prosecution of offenders. Might he draw the attention of the Conference to one instance at the present time. The West Riding Rivers Board had to get the permission of the Local Government Board before they could

institute prosecutions. What happened ? The Board sent to the Local Government Board for leave to prosecute other sanitary authorities for the pollution of rivers. They sent to the Board, and sometimes two, three, four, or six months elapsed before they got permission. He was sure no member of this Conference wanted to perpetuate any system of that description.

By all means let the Bill provide for a grant of £10,000. But he thought the cause would be advanced if they were to omit the whole of that part of the Bill which dealt with the Local Government Board, rather than bring local authorities—or local smoke prevention authorities, whichever were set up—within the purview of the Local Government Board. This would to a certain extent hamper the work of the authorities, and he doubted whether the financial gain—which was really what they were seeking, he presumed—would compensate for the irritation the authorities would have to suffer if they were to be hampered in their activities, as he was afraid they would be if the Local Government Board was permitted to exercise a greater control than it had to-day.

It occurred to him that there was another difficulty with regard to the local authority. Assuming that the Bill became law in the form in which it was drafted, they would have a local smoke prevention authority, endowed with certain powers, and they would still have the urban sanitary authority, which was endowed with certain powers under the Public Health Act of 1875. They would thus have a dual authority working towards the same end. As the Urban Sanitary Authority already had certain powers, would it not be better to make the work of the local authorities easier than it was to-day rather than take away from them the work of which they had already had considerable experience, and which would enable them to carry out these new powers much better than if they were placed in the hands of any new authority.

With regard to Sir John Bingham's remarks about the smoke inspector being an independent person, he wished to point out that in a properly governed community the Health Committee had only one object in view—to protect the public and to protect the public health. Surely if that was the object with which they set out, they could not be regarded as prejudiced persons if they had an ideal and a duty to the public. And surely it could not be wrong to put under them the persons who were to seek out offenders and carry out the law, and secure that the offenders were penalised.

Sir John Bingham asked if he might refer to what the last speaker had said about the employment of smoke inspectors. He did not wish to make any charge, but it was pretty well understood that their inspector, who by his strictness injured some of the Sheffield manufacturers, was very soon dismissed. It was very hard on an inspector to know that by being as strict as he ought to be, he would very possibly forfeit his situation. This could not occur if he were employed under the Local Government Board. (Hear, hear.)

Mr. Sixsmith (Oldham) thought that the main reason why the powers under the Public Health Act had been very little utilised should be mentioned. He knew some very bad chimneys and he should be very glad to go to the trouble and expense of a prosecution in one case did he not know that the bench of magistrates were "pals" of the owner and were most of them sinners in the same respect. The inspector ought therefore to be independent and not under their control. It was also the case that in large manufacturing villages in Lancashire generally the Urban District Council was influenced too much by the local manufacturers. (Hear, hear.) It was very important that the inspectors should be appointed nationally and be quite independent of all local influence. (Hear, hear.) As regards domestic fires would it not be proper to introduce into the Bill a provision that just as drains of houses are passed the authorities should also pass the fireplaces. (Hear, hear.) A certain class of fireplaces would then be avoided.

Alderman Bennet (Warrington) said that theoretically everyone thought that the local authority ought to deal with this question, but in practice that did not work out at all. In his own town—Warrington—the Corporation neglected their duty in this matter very seriously. The only way to deal practically and drastically with the matter was to have an outside authority, able to act without fear or favour, and solely in the interests of the whole community. (Hear, hear.) Sentiment seemed to count for everything. The one idea was that in dealing with this matter they were interfering with local industry. And if there was one god before which the local Councils wallowed it was the god of local industry. (Laughter.) They could only try to educate the public to an enlightened point of view and try to bring pressure upon Parliament so that local authorities might carry out the duties so deplorably neglected by the majority of them.

Mr. Anderson (Sanitary Inspector, Middlesbrough) said that the greatest difficulty in carrying out the Public Health Act was

that black smoke must be emitted in such quantities as to be called a nuisance, whereas they could have any amount of nuisance without black smoke. (Applause.) Every inspector was trying to carry out this Act, but the probability was that if an inspector pitted himself against a powerful firm he stood a good chance of getting notice to quit. If the inspector could feel that the Local Government Board would support him he thought a good deal would be done in the direction they desired.

Mr. Morton (Glasgow) said that in Glasgow the local authority had perhaps done more than any other local authority for smoke abatement, and if they included a clause in this Bill to create another authority, they would first of all get the opposition of the present local authorities. (Hear, hear.) He hoped the Bill would be re-committed to the Executive for further consideration.

Several other delegates took part in the discussion.

Mr. Graham, replying to the discussion, urged that 28 municipalities were responsible for the proposals contained in the Bill, and that these proposals were made and brought before the Local Government Board with the support of the local authorities. To meet the difficulty raised by Mr. Watling that large towns would object strongly to having their powers reduced he proposed that in districts where local control was inefficient the Local Government Board should set over a large district—including perhaps half a dozen or a dozen local authorities—a board, like the Mersey and Irwell Committee, for joint action. Towns like Bradford, Manchester, or Glasgow, which did their duty properly, would remain in full control of their present work. Only in cases of neglect of work by local authorities would the Local Government Board press them. The object had been that there should be some stimulation of local authorities, while retaining in them all that was valuable and useful and avoiding duplication. It had been shown that only seven or eight local authorities throughout the country paid anything like adequate attention to smoke prevention. They wanted to stimulate authorities who neglected their work, and help those who looked after it. They did not propose that the Local Government Board should be communicated with before prosecutions were taken up. The local authorities would prosecute whenever they liked.

EFFECTS OF COAL SMOKE.

By Prof. J. B. COHEN, B.Sc., Ph.D., F.R.S.

The subject of the emission of coal smoke from chimneys is one which has for many years past forced itself with increasing prominence upon the notice of those residing in the larger towns. It is admittedly its æsthetic rather than its economic aspect which has appealed in the first instance to popular sentiment. Blackened buildings, darkened skies, and the general air of dirt and gloom, which are typical of an English industrial centre, have aroused a growing feeling of dissatisfaction among a certain section of the community, and have led to the formation here and there of societies for the prevention of smoke. Some of these societies, like the one in Manchester, have pursued their object with great energy, and have sought by means of pamphlets, public addresses, and exhibitions of smoke-preventing appliances to enlist public sympathy.

It is a remarkable fact, nevertheless, that in face of the active propaganda of these societies and a very widespread sympathy with their aims, as well as the existence of certain legislative measures directed against the smoke of factories, the emission of smoke continues with almost unabated vigour.

The reason is twofold: there is the inertia of established custom which resists any change, and, secondly, there are private and commercial interests which always dominate an industrial community. The authorities are unwilling to interfere with the business of the manufacturer or the liberty of the private citizen. It is useless to appeal to them on the ground that coal smoke is unsightly or in a vague sort of way that it lowers vitality or destroys vegetation. Æsthetic considerations possess little weight with the Legislature, and the effect of smoke on health must be very clearly proved before action is taken. Thus, no President of the Local Government Board has yet ventured to pledge himself to any definite policy for meeting the evil in a more effective way than our present system affords, however inadequate that may be. Not even

the enormous aggregate loss of fuel, which coal smoke entails, disturbs him. That is a private concern of the householder and manufacturer. Thus, matters are at a standstill.

If we are going to appeal effectively to the public, or to the public authority, we must do one of two things, either show (1) that the community is throwing money away that might be saved, or (2) that it is suffering moral or physical injury. In connection with the contamination of our atmosphere, medical statistics would be most valuable. Consider the effect on our breathing organs. Every man and woman of us breathes about 2,000 gallons of air in 24 hours, or about 34 lbs. weight, as against $5\frac{1}{2}$ lbs. of liquid and solid food, or six times the weight, and it is inconceivable that a human being can breathe an atmosphere vitiated by smoke without his lungs becoming affected. Yet it is remarkable that whilst every municipality pays the most scrupulous attention to the purity of its food and water supply, it leaves the atmosphere to take care of itself in the sense of neglecting any supervision of its condition or its physiological effects.

It is quite true that the mortality from pulmonary diseases is much higher in the town than in the country, but we cannot single out smoke as the cause, because the problem is complicated by so many other factors, such as the effect of indoor and sedentary occupations. We also possess statistics contrasting different areas of the same town, but the same criticism applies to these figures. The only statistics known to me which are beyond question are some collected by Dr. Ascher, Medical Officer of Königsberg, in E. Prussia. He has selected two districts in the industrial area of Westphalia, one (Gelsenkirchen) in the centre and one (Hamm) on the eastern border. The populations are respectively 37,800 and 32,400, and they are engaged in similar trades. Mortality from acute non-tuberculous pulmonary diseases (such as chiefly affect colliers, coal heavers, and chimney sweeps) is, in the central area, 57·4 and on the fringe of the area 30·6 in 10,000, and the difference is greatest (almost three times) between the ages of 15 and 60. These are the kind of statistics that we want, and come under the category of physical injury to the community.

The question then arises: what information have we on the effects of smoke? What is the nature of soot? What is the quantity emitted from domestic and factory chimneys, and what is the quantity temporarily and permanently deposited? What is the quantity suspended in the air, and to

what extent does such an atmosphere affect health? Does smoke corrode as well as discolour masonry and brickwork, and how far is it destructive to vegetation? Do its effects extend beyond the immediate vicinity of the town? To what extent does it shut out daylight, induce or aggravate fog, and finally what is the increased national washing bill?

It is to some of these questions that Mr. Ruston and I have been trying to obtain definite answers. We have not entered at all into the subject of the cause and cure for smoke, which have been very thoroughly examined and discussed by other writers. Our attention has been directed to collecting together data on the imperfect combustion of coal, and presenting an accurate picture of its results.

The Composition of Soot.

Soot consists mainly of carbon, tar and mineral matter (ash). If it were entirely composed of carbon and mineral matter it would be rapidly removed by the first heavy rainfall, and there would be probably no steady accumulation of grime on brickwork, masonry, and vegetation, such as strikes the eye on entering a large town. But the tar which soot contains causes it to adhere like a varnish even to the polished surface of glass, from which not even a strong current of water will detach it. As the tar is produced by slow combustion, that is, in the absence of a strong draught, one would expect domestic soot to be richer in that ingredient. This is the case. The following analyses in parts per 100 have been made with the same coal burnt in a domestic grate, and in a boiler furnace, and collected from the flues.

Constituents.	Original Coal.	Soot from Ordinary Firegrate.	Soot from Boiler Chimney.	
			Bottom.	Top.
Carbon	69·30	40·50	19·24	27·00
Hydrogen	4·89	4·37	2·71	1·68
Tar	1·64	25·91	0·09	1·14
Ash	8·48	18·16	73·37	61·80

This contribution of domestic soot, with its high content of tar, in aggravating the smoke problem, cannot be underestimated.

Acidity of Soot.

Dr. Russell many years ago observed that soot contains sulphuric acid, and that water was always rendered acid by the admixture of soot. We have found the same thing in all the specimens examined (except that from a brass foundry which burnt oil containing no sulphur), the quantity varying from ·28 to 1·62 per cent.

The Amount of Soot emitted from Chimneys.

It is very difficult to obtain trustworthy data in regard to factory chimneys owing to the varying quality of coal, size and structure of chimney, and irregularity of firing; but Scheurer-Kestner, in a very careful research on flue gases from boiler furnaces, puts the amount at 0·5 to 0·75 per cent. The late Sir W. Roberts-Austen made a large number of determinations on the quantity of soot from domestic fire-places, and from his data a rough estimate can be made, which is rather over 6 per cent. My own results, carried out with a variety of different kinds of coal, concord very well with his results. We can now estimate the national loss of fuel from these two sources. Taking the average loss at 6 per cent. on the 32 million tons of coal used for domestic consumption and 0·5 per cent. on 100 million tons used for industrial purposes, we get—

32,000,000 at 6	per cent.	=	1,920,000
100,000,000 at 0·5	,,	=	500,000
			2,420,000

These figures do not, of course, imply the saving which might be effected by more efficient utilisation of the fuel.

Amount of Solid Impurities in the Air.

The first accurate experiments on the quantity of suspended organic matter in the air were made by the late Dr. Russell on London air. He found the following quantities for fine, dull, and foggy weather in milligrams, per 100 cubic feet:—

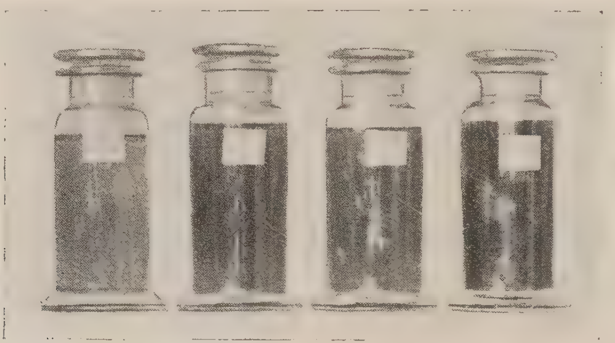
Fine weather	0·35
Dull ,, ...	1·03
Foggy ,, ...	2·44

Experiments carried out in Leeds agree very closely with these observations, being on the average 1·2 milligrams per 100 cubic feet. Supposing the soot to be uniformly distributed to a height of 300 feet before being dispersed, according to Dr. Angus Smith's estimate, and further, that the atmosphere is renewed 50 times in 12 hours, a simple calculation shows that

5 tons to the square mile is daily discharged into the air of Leeds, and that 2 cwt. is suspended at any moment over one square mile.

The Daily Sootfall.

This has been estimated by collecting snow on four consecutive days during clear weather, and also rain water. The following diagram represents the specimens of melted snow. The amount of soot carried down on the first day, estimated by filtering the liquid and weighing the soot, amounted to 240 tons per square mile per annum.



First day. Second day. Third day. Fourth day.

The amount of suspended matter carried down by rain was determined by placing bottles (into which a large funnel was inserted) at different stations within and beyond the town. The character of the station and the quantity in tons per square mile are given in the following table.

Solid Impurities in Rain Water.

(TONS PER SQUARE MILE PER ANNUM.)

Station.		Suspended Matter.			
		Carbon.	Tar.	Ash.	Total.
Industrial	Leeds Forge	189·6	31·4	318	539
	Hunslet	241·2	19·7	187·2	448
	Beeston Hill	87·1	42·6	202·5	332
Town	Philosophical Hall	99·7	22·3	120·6	242
Residential.	Headingley	100·2	12·3	56·9	188
	Armley	98·0	9·7	61·7	169
	Woodhouse Moor	63·2	9·1	41·7	114
	Kirkstall	52·3	8·0	40·3	100
	Weetwood Lane	19·2	7·4	15·4	42
	Roundhay	7·7	4·0	14·0	25
Country	Garforth	—	—	—	—

The average for the whole town area is approximately 220 tons per annum per square mile, and this represents wasted fuel.

The same results are shown diagrammatically on Fig. 2; the black portion of each column represents carbon, the shaded portion, the tar and the white portion, the ash.

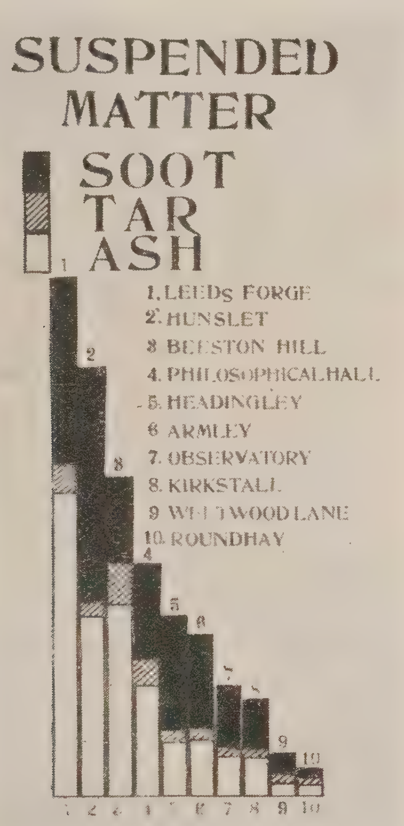


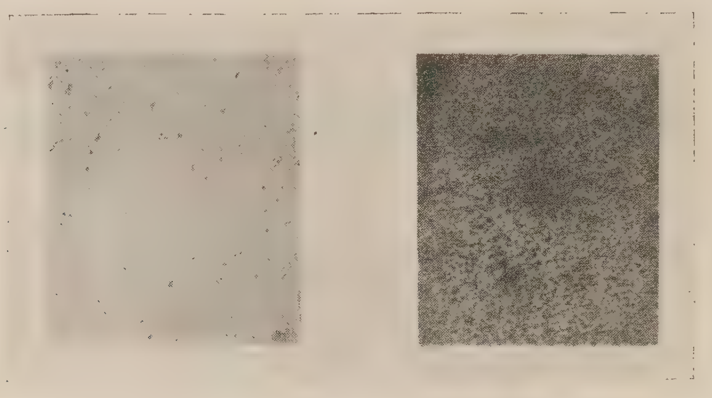
Fig. 2.

The Deposit of Soot-Tar.

In addition to the above figures, the quantity of adhesive soot or soot-tar has been estimated by analysing the permanent deposit on glass plates of given dimensions placed at different centres for periods of three months, and then, after washing off any loose deposit, estimating the residual adhesive matter. This adhesive deposit, which causes a permanent and steadily increasing discoloration of buildings and vegetation, decreases enormously on passing from the centre to the outskirts.

Fig. 3 represents a photograph showing the appearance of two glass plates exposed for the same period of 6 months, one in

Leeds and the other about 5 miles distant from the town.



Country. Town.

FIG. 3.

The following records were obtained :

Deposits of Soot-Tar.

	Station.	March to June. 1910. M.grms.	June to Sept. 1910. M.grms.	Cwts. per sq. mile per annum.
Industrial Area.	Hunslet	52·6	46·5	110
	Kirkstall Road ...	26·2	31·1	64
Town Area.	Philosophical Hall.	26·4	30·4	63
Residential Area.	Headingley	11·3	17·2	27
	Woodhouse Moor..	15·4	9·0	32
	Roundhay	2·0	2·1	4·5

From 110 cwts. per sq. mile per annum deposited in an industrial centre in Leeds it fell to $4\frac{1}{2}$ cwts. at Roundhay situated about two miles away.

Calculating the coal consumption of Leeds in factories and domestic fire-places from the proportion per head of the whole population of the country, we have the following amount of soot and its ultimate destination as regards Leeds :—

	Tons per annum		Tons per annum
Total soot from factories...	5,000	Soot blown away ...	31,480
,, ,, house-fires	30,000	Temporary deposit..	3,472
		Permanent ,, ...	48
	35,000		35,000

The amount which escapes is ten times that which falls and about 600 times that which remains as a permanent stain.

Sulphuric Acid from Coal and its effects on Masonry and Ironwork.

A considerable quantity of sulphuric acid is produced from the sulphur in coal on burning, and attacks not only vegetation in a very marked degree, but also masonry and iron. Mr. Ruston will deal with its effects on vegetation, and I will therefore restrict my remarks to the other two points. As the products of combustion of coal contain ammonia, a certain amount of the acid is neutralised and is thereby rendered innocuous. The amount of free acid is, however, considerable, and the following table shows the amount in tons per square mile per annum carried down by rain-water at different stations in and near Leeds :—

Station.	Tons per sq. mile per annum Free Sulphuric Acid.
Leeds Forge	10
Hunslet	26·7
Beeston Hill...	8·5
Philosophical Hall	12·9
Headingley	3·1
Armley	8·3
Woodhouse Moor	7·5
Kirkstall	2·3
Weetwood Lane	3·1
Roundhay	0
Garforth...	8

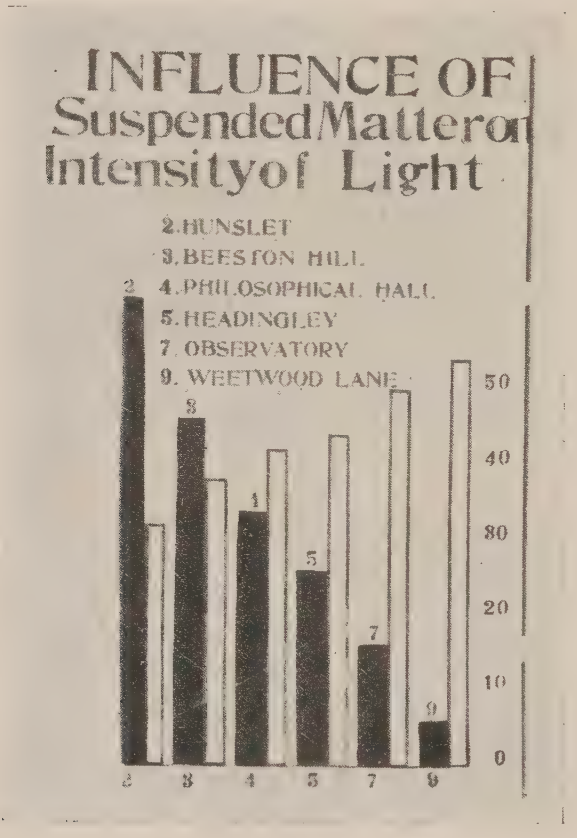
The quantity varies considerably and depends partly on the accompanying amount of ammonia and partly on the locality. Garforth, seven miles east of Leeds, lies on the side of the prevailing winds and no doubt gets much of the latter's smoke. It also has collieries in the neighbourhood. Prof. H. Jackson, of King's College, London, has supplied me with valuable information on the corrosion of masonry, and has collected a large number of facts showing how the acid is steadily eating away and destroying the stonework of some of our historic buildings.

I am further indebted to the chief engineers of the Midland and Lancashire and Yorkshire railways for observations carried out systematically during the last 17 years, showing the marked effect on rails produced by corrosion from the atmosphere of

towns as compared with those in the country. The loss of weight in the town was six times that in the country.

Effect of Smoke on the Intensity of Daylight.

The presence of suspended matter in the atmosphere has a marked effect upon the amount of sunshine. As an illustration we may take the year 1907 when the number of hours of sunshine registered by a Jordan recorder in the centre of Leeds was 1167 as compared with 1402 at Adel about 4 miles away, in other words, the duration of sunshine in the centre of the city was diminished by 17 per cent. The records of other years tell a similar tale. But the sunshine recorder takes no account of the intensity of light below a certain limit of brightness. The amount of daylight may, however, be determined sufficiently accurately for comparative tests by the amount of iodine



liberated from an acid solution of potassium iodide. Two sets of experiments were made, one in 1895, chiefly during the winter months and another set in 1910 during the month of June.

According to the first set the amount of daylight cut off by smoke in the centre as compared with the outskirts of the town amounted to about 25 per cent. on the average, and in the second set where a comparison was made between the Leeds industrial area and the neighbouring country village of Garforth (7 miles east of Leeds) the loss of light was about 40 per cent.

The preceding diagram represents the relation between the amount of suspended matter in the air (black column) and the amount of daylight (white column) at the same station, from which it will be seen that as the amount of suspended matter decreases that of the light increases.

In conclusion I should like to refer to the independent statements of two of the most distinguished technical chemists of the day in regard to the utilisation of coal. Mr. Beilby in his evidence before the Royal Commission on the Coal Supply stated that, through inefficient methods of burning coal, something like 60 million tons were wasted annually in the United Kingdom.

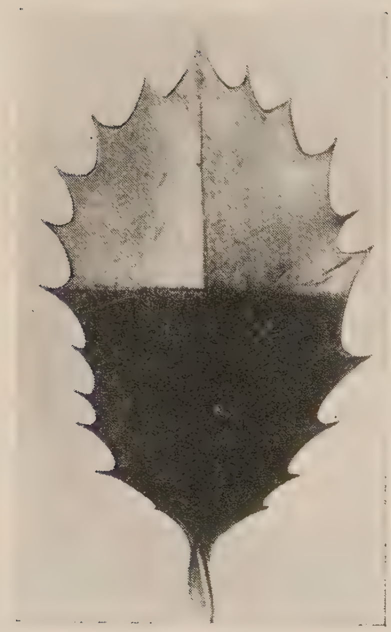
Prof. O. N. Witt, in his address to the International Congress of Applied Chemistry held in London in May, 1909, said: "There was a time both in England and on the Con- "tinent when smoke was considered a necessary evil and "had to be suffered. After a while smoke began to be "looked upon as a nuisance, and war was declared against it "by those who suffered from its disagreeble properties; but "now we know that smoke is a waste and that nobody has "better cause to wage war against it than he who produces "it. Smoking chimneys are thieves, and their misdeeds "should not rise unavenged to heaven. . . . It is, perhaps, "not too much to say that the saving of national wealth "effected by gas heating may amount to a sum sufficient to "pay the aggregate national debts of all the civilised "nations."

EFFECTS OF SMOKE ON VEGETATION.

By ARTHUR G. RUSTON, B.A., B.Sc.

That smoke does exert a very prejudicial effect upon the growth of plants is a self-evident fact, only too manifest to anyone who has the fortune or misfortune to live in one of our northern manufacturing towns. It is, however, only of recent years that careful and continuous investigations have been made with a view to determining, first the extent to which this damage to vegetation by smoke does occur, and second the factors which influence it.

Professor Cohen, in a paper read to you this evening, has dealt with the amount of impurities due to coal smoke which are present in the air of towns. These impurities will be potent factors, both directly and indirectly, in hindering plant growth; directly by checking assimilation, and indirectly by their action upon the soil. By far the greater part of the material of which the plant is composed is taken from the atmosphere. The leaves of plants possess minute pores or stomata, by means of which they absorb carbon dioxide from the air, this carbon dioxide being converted in the plant into starches, sugars, or other carbohydrates. Anything, therefore, which will tend to hinder this intake and assimilation of carbon dioxide will effectively hinder the growth of the plant. Now soot is not pure carbon, but contains from 10 up to occasionally as much as 40 per cent. of a thick oil. By virtue of this it adheres tenaciously to anything with which it may come into contact, so that it cannot easily be removed by the rain. A black adhesive film covers the smoke-infested area with a permanent and ever-deepening coat of fast colours. It is this adhesive deposit which discolours buildings and blackens vegetation. The leaves of trees, and of evergreens in particular, get coated over with this black deposit, as can be



seen from the accompanying photograph, for which I am indebted to Professor Cohen. The upper part of this holly leaf has been cleaned to remove the deposit as far as possible, the lower part being left untouched, and the whole then bleached to extract the chlorophyll or green colouring matter. Unfortunately, it does more than blacken the vegetation; it covers the whole leaf with a kind of varnish and fills up the pores or stomata, most effectively checking the natural process of transpiration and assimilation. True, the stomata, in the case of most plants, are situated on the underside of the leaf, while the greater part of the grime and dirt will naturally settle upon the upper surface. Still, an examination of the leaves of many plants shows that they by no means escape unhurt. Evergreens suffer most in this respect, because they have also the winter smoke to contend with. Of the evergreens the most susceptible seem to be the conifers. The leaves of these trees are small and easily shaken by the wind, so that any deposit will readily settle both upon the upper and lower surface; in many cases, too, the stomata are fairly equally distributed upon both the upper and lower surface. Above all, they possess what are known as "sunk stomata," which while they afford very efficient protection against undue evaporation, form also very efficient traps for smuts and dirt when the trees are situated in atmospheres such as those of our large industrial towns. It is no uncommon thing

to find in the case of the leaves of conifers grown in Leeds that 80 per cent. of the stomata are choked up with tar, as in the case of the illustration given here. The only two localities in

Stoma of Silver Fir

Leeds in which conifers will thrive are those which stand out clearly as possessing the least smoke-infested atmosphere.

	Annual fall of Soot.
Weetwood Lane	147 lbs. per acre.
Roundhay	90 ,, ,,

It is doubtful indeed if they would do well in any district where the solid impurities deposited yearly amounted to 200lbs. per acre.

Again, the effect of these solid impurities in diminishing the amount of sunlight in our industrial towns may be gathered from the fact that in 1907 the number of hours of bright sunshine registered in the centre of Leeds was 1167, as compared with 1402 at Adel, some four miles to the north. In other words, the smoke-cloud hanging over the centre of the town has curtailed the duration of bright sunshine by fully 17 per cent. If, however, we measure not the number of hours of bright sunshine, but the actual intensity of the light, by the method already explained and described by Professor Cohen, we find not only a greater curtailment, but also a sharply-defined correlation between that

intensity and the known solid impurities in the air, as the following table will show :—

Station.	Solid impurities reaching the ground yearly.	Intensity of light. Arbitrary scale.
Hunslet	1,565 lbs. per acre	32
Beeston Hill	1,163 ,, ,,	35
Philosophical Hall	849 ,, ,,	40
Headingley	659 ,, ,,	42
Observatory	399 ,, ,,	47
Weetwood Lane	147 ,, ,,	54

In Hunslet, therefore, the centre of one of our chief industrial areas, fully 40 per cent. of the light is shut off. The energy of sunlight is required by the green leaf for the conversion of carbon dioxide into carbohydrates, and when 40 per cent. of this energy is cut off by the smoke cloud, the effective growth of the plant must be very considerably checked.

If the plant obtains the greater part of the material of which it is composed from the air through the assimilation of carbon dioxide, the measurement of that assimilation by a unit area of leaf in unit time should give its measurement of effective growth. It was interesting, therefore, to compare this assimilation in the case of laurel leaves of the current year's growth, grown in different parts of Leeds. Taking those grown in Weetwood Lane as our standard, it was found that on the same day, with the same temperature and the same intensity of light, the assimilation of different leaves from the same locality was approximately constant. If, however, we take leaves from the same locality, their rates of assimilation will vary day by day, depending upon the temperature and intensity of light.

In other words, the smoke-cloud continually hanging over our industrial areas will have in this respect a very marked influence in limiting the growth of plants.

If, again, we compare, on the same day, the assimilation of leaves grown in the Weetwood Lane and in some more impure

district, we always find the leaves from the purer district possess the greater power of assimilating carbon dioxide.

Experiment No.	Source of Leaves.	Area of Leaves. sq. in.	Intensity of Light. cc. $\frac{N}{10}$ Iodine	Hourly mean Temperature. degrees C.	Total CO_2 assimilated. milligrams.	CO_2 assimil'd per 10 sq. in. per 10 hrs. milligrams.
1	Weetwood Lane	36·21	1·22	10·8	21·56	5·95
2	Weetwood Lane	23·5	3·4	17·6	40·48	17·2
3	Weetwood Lane Weetwood Lane	23·52 29·84	1·9	13·7	36·08 37·64	11·51 11·82
4	Weetwood Lane Headingley Hill	29·84 24·35	1·78	18·0	38·72 16·72	12·99 6·86
5	Weetwood Lane University	29·84 12·54	2·12	12·6	34·32 6·04	11·50 4·81
6	Weetwood Lane Hanover Square	29·84 15·62	0·46	14·8	29·04 2·20	9·73 1·48
7	Weetwood Lane City Square	28·64 16·42	2·8	17·6	47·21 2·64	13·52 1·56

Using this as our measurement of the growth of plants from different districts, we can give them the following values :—

Station.	Annual deposit of soot.	Assimilatory powers.
Weetwood Lane	147 lbs. per acre	100
Headingley Hill	273 ,, ,,	53
University	399 ,, ,,	42
City Square	849 ,, ,,	12

As was to be expected from the above figures, the laurel plants found in the more polluted areas were all stunted in size as compared with those grown in the Weetwood Lane district, while in Hunslet, one of the most polluted areas, a two days' search failed to find any trace of laurels which had survived the ordeal.

The majority of the samples of rain collected at the different stations were decidedly acid to methyl orange,

indicating the presence of free mineral acid, principally sulphuric acid arising from the combustion of coal. Free acid must be actively detrimental to vegetation, both by

its direct action upon the leaves and by its slower action upon the soil. The deposition of acid along with soot upon the leaves of plants is probably one of the main causes of the early withering, which is so characteristic of many forms of town vegetation, notably trees. Ash trees in the purer parts of Leeds often retain their leaves some four or even six weeks longer than those in the more contaminated districts. Thus, on September 18th of this year in Hunslet, with suspended matter 1,565lbs. and acidity 90lbs. per acre, all the ash trees which were alive were found to have shed their leaves; while at Roundhay, with suspended matter 90lbs. per acre and acidity nil, practically all the ash trees were in full leaf at the beginning of November.

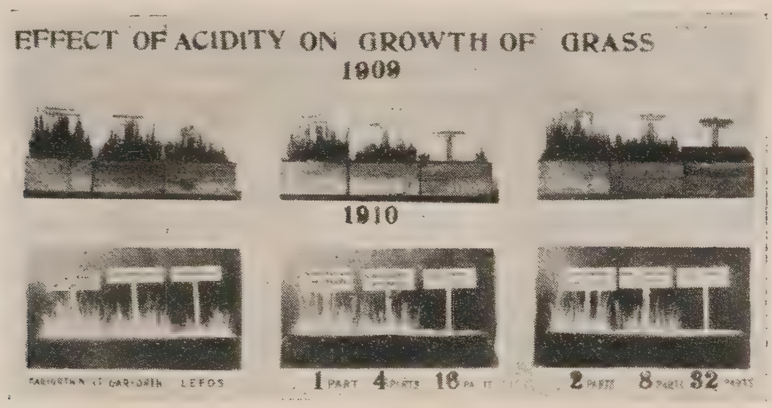
If, therefore, we look upon the leaf as the factory of the plant, we find that owing to the smoke pollution the factory is actually closed for six weeks out of the four or five months of its working year, while during the remainder of the time, as our assimilation experiments show, it will be working at less than half its normal pressure.

The tree automatically keeps a record of its yearly growth, and the presence of any inhibiting factor will make itself known by the narrowing of the annual rings. This is well seen in the case of the section of the Scotch fir illustrated here, for which

I am indebted to Mr. D. W. Steuart. The tree in question was grown at Broxburn, where shale retorts were opened in 1893. Coincident with this, as can be seen by counting back the number of rings, is a sharply-defined check in the yearly growth.

With the object of ascertaining the effect of free acid on plants, Timothy grass was sown on May 12th, 1908, in a series of boxes one foot square, filled in each case with soil from the same field. These were watered at rates corresponding to the average annual rainfall of 25 inches with Garforth rain water neutralised, Garforth rain water unneutralised, Leeds rain water (the acidity of which varied from ½ part to occasionally, during fog, as much as 10 parts per 100,000), and also with water containing 1, 2, 4, 8, 16, and 32 parts of sulphuric acid per 100,000. In the case of Leeds rain water and of those waters containing the higher degrees of acidity, germination was distinctly checked, and the delicate green of the young grasses quickly changed to a yellow or brown. The grasses watered with water whose acidity was 32 parts per 100,000 were killed off in little more

than three months, and not a trace of vegetation of any kind was visible in the following spring, while the water whose acidity was 16 parts per 100,000 proved fatal in less than a year. It was also shown that while the final effect of acidity was to destroy



vegetation altogether, smaller amounts had the effect of reducing both the quantity and quality of the herbage. Thus in every case a larger amount of acidity meant a decreased yield, an increased fibre content, indicating that the grasses were indigestible, and a decreased protein or albumenoid content, indicating a low feeding value.

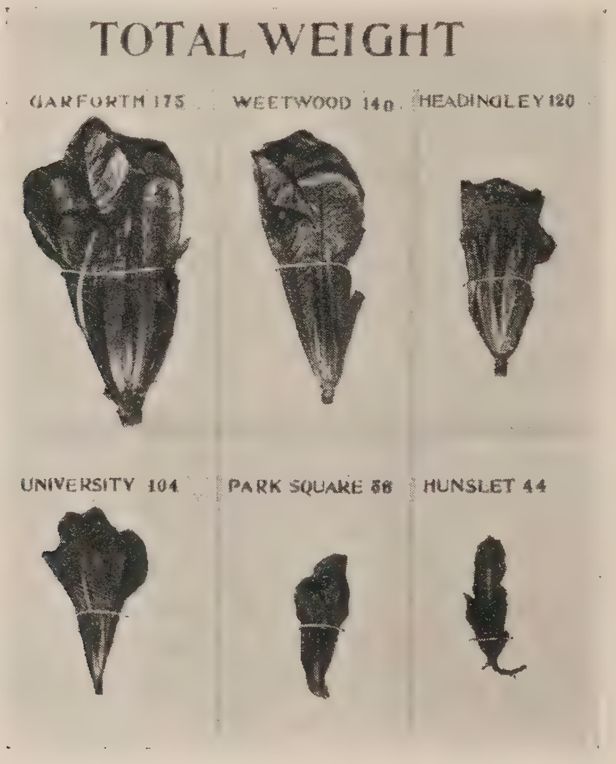
Description of water used.	Total Dry Matter.			Crude Protein in Dry Matter.			Crude Fibre in Dry Matter.		
Year.	1908	1909	1910	1908	1909	1910	1908	1909	1910
	gms.	gms.	gms.	%	%	%	%	%	%
Garforth rain, neutralised	28·0	24·9	14·7	15·44	13·87	9·88	24·3	21·9	23·7
,, ,, ordinary..	24·8	18·5	11·0	12·56	10·96	9·62	25·9	25·3	26·0
Leeds rain	23·8	17·5	6·6	12·25	8·88	7·67	26·4	26·3	27·2
1 part H_2SO_4 per 100,000	30·5	18·2	12·0	11·82	10·06	8·75	25·5	27·3	26·2
2 parts ,, ,, ,,	28·7	17·8	8·0	11·50	6·63	6·81	26·3	28·8	28·7
4 ,, ,, ,, ,,	28·8	10·0	3·9	10·87	5·94	5·38	27·4	28·9	28·9
8 ,, ,, ,, ,,	24·8	8·2	3·7	11·07	5·56	5·13	28·2	33·4	30·3
16 ,, ,, ,, ,,	23·8	1·8	nil	10·13	5·44	—	30·8	36·2	—
32 ,, ,, ,, ,,	14·1	nil	nil	5·82	—	—	31·6	—	—

The effect of the acidity in the soil was shown most markedly in the reduction in the number and activity of the soil bacteria, of which the most valuable and at the same time the most sensitive, are the nitrifying organisms.

The following table, giving, after three years, the yield in dry matter of grass and the number of bacteria per gramme of the soil, shows what powerful factors bacteria are in influencing the fertility of the soil, and also suggests still another way in which smoke pollution may damage vegetation.

	Yield of Dry Matter, 1910.	Colonies per gramme of soil.
Garforth rain, neutralised	14·7 grammes.	5,228,000
,, ,, ordinary ..	11·0 ,,	1,690,000
Leeds ,, ...	6·6 ,,	1,170,000
1 part H_4SO_2 per 100,000	12·0 ,,	1,260,000
2 parts ,, ,,	8·0 ,,	1,110,000
4 ,, ,, ,,	3·9 ,,	690,000
8 ,, ,, ,,	3·7 ,,	130,000
16 ,, ,, ,,	Nil.	40,000
32 ,, ,, ,,	Nil.	15,000

During the last year various vegetables have been grown in different parts of the town, in the same soil and under the same conditions, except atmospheric conditions. The results, so far as



they are to hand, prove conclusively that smoke pollution does actually and definitely exert a very prejudicial influence upon garden crops, a fact which must be of vital importance to every one of you. Thus in the case of radishes, only half the crop was secured in Hunslet, and in the case of lettuces only one quarter the crop that should have been secured, had the atmospheric conditions been purer, and smoke pollution been less.

Locality.	Solid deposit.	Acidity.	Crop of Radishes.	Crop of Lettuces.
	Lbs. per acre.	Lbs. per acre.	Gms.	Gms.
Weetwood Lane	147	11	496	140
Headingley Hill	273	19	449	120
University	399	26	297	104
Park Square	849	45	242	56
Hunslet	1,565	90	226	44

The points, therefore, that I wish specially to bring before your notice are :—

I.—That it is possible to get a measure of the effective damage to vegetation by smoke.

II.—That the factors in smoke pollution which prejudicially affect vegetation are :—

a. The smoke cloud limiting the available sunlight.

b. The tarry matter coating over the leaves and choking the stomata.

c. The presence of free acids in the air, tending generally to lower the vitality of the plant.

d. The effect of the free acids falling upon the soil and limiting the activity of the soil organisms, principally the nitrifying organisms.

The last factor can very effectively be dealt with by a simple application of lime, while the first two can only be met by checking the output of smoke, and using every effort to lessen the air pollution, which is the ruin of many of our crops.

THE RELATION OF SMOKE AND HEALTH.

By JAMES NIVEN, M.A., M.B., LL.D., Medical Officer of Health, Manchester.

(This paper was printed in the Catalogue of the Exhibition, and was not read at the Conference.)

A few preliminary considerations are necessary before we can profitably discuss the relations of smoke to health.

In the year 1773 Manchester was a small town on the banks of the Irwell, and beyond the Cathedral were green fields. In that year the population of the Manchester Township was 22,481. But shortly after that period the era of industrial expansion began, so that in 1837 the population of the township was 168,911. The largest population in this area was recorded in the year 1851, when it was 186,986. From this time forward the population of the central part of the city declined, at first slowly, then more rapidly as warehouses and other places of business were erected, until in 1901 it had declined to 132,316. At the last census it is not likely to have exceeded 120,000.

The chief industry towards the end of the eighteenth century was weaving, afterwards spinning and weaving, at first of woollen, subsequently of cotton goods. The houses were gathered round courts, with midden privies in the centre.

About 70 years ago Hulme was developed, chiefly as a residential district, and there being no building bye-laws, the long rows of houses were placed very near to each other in the rear, with narrow passages, and small yards. These were blocked at the ends, so that, given the collection of fæces in the rear of the houses, the conditions were about as bad for health as could be imagined.

Building bye-laws first came into operation in the year 1868. But up to that period no damp-proof course was inserted between the houses and the soil, so that the inhabitants were exposed to loss of energy by the cooling effect of evaporation proceeding within the houses. This factor in the production of bad health has continued up to the present time, and must continue for some time longer, so far as the older houses are concerned. Manchester is naturally a badly-drained area, since, though to the north and east the ground rises fairly steeply, on the south and west the surface has but little fall. It is true that the watersheds of the Irwell and Medlock are covered with sand and gravel, but the greater part of the surface is covered with drift clay, which is at once impervious and retentive of moisture.

Nor, with the methods of storing excreta in use up to recently, was any advantage to be derived from beds of sand, since these only served to diffuse organic filth over larger spaces.

In order that due advantage may be obtained from the river-side sand beds, all deposit of filth on permeable surfaces must be obviated.

We have seen that the township of Manchester increased rapidly in population during the era of industrial expansion. But the increase was not confined to the Manchester township. Thus, shortly after the incorporation of the Borough in 1838, its population was enumerated in 1841 and found to be 242,983. The area was then 4,293 acres.

In 1885 it was extended to include 5,933 acres, and in 1881 the population was 373,583. A further extension occurred in 1890, raising the area to 12,935 acres. In 1891 the population of this extended area was 505,368, and in 1901 543,872. In 1904 and 1909 further extensions occurred, raising the area to 21,646 acres, and at the census in 1911 the population of this extended area was found to be 714,427. These successive extensions have brought the city nearer and nearer to coincidence with the three Unions of Manchester, Chorlton, and Prestwich. In fact Chorlton Union is now entirely absorbed, and only a small part of Prestwich Union remains to be taken in. Numerous works have been erected. In the first half of the eighteenth century these arose amidst and loomed over the houses. Their tendency in more recent times is to advance in the eastern portion of North Manchester.

In consequence of the improvement in building requirements, the population is now spread out over comparatively large areas, with the result that from whatever quarter the wind blows we get smoke wafted to the more central portions of the city. To the west we get smoke from Salford, to the east from Manchester, Failsworth, and Oldham, to the south from Stockport, and so forth.

As the city has grown, great changes have taken place in the social status of the inhabitants. The proportion of persons earning what we may roughly call a living wage has steadily grown, and though knowledge of how to live well lingers, it advances also. Much of the improvement in health noted is due to this relative increase of persons who are able to live comfortably.

The Measure of Health.

We have no measure of health except the death-rate, and no doubt this is an imperfect measure. We may confidently assume that the health of the community has not improved to the same extent as has the death-rate. But we possess no comparison of health rates, nor are we ever likely to do so, unless the health rate is unaltered by the introduction of a system of national insurance. So great have been the advances in medicine and surgery, and so remarkable the efforts of benevolence in the provision of public hospitals, that it is quite certain that many lives are now saved annually which would have been lost fifty years ago.

On the other hand it cannot be doubted that the physique of young children has improved, and indeed of the community generally. Nor is it conceivable that the saving of life as measured by the figures as between now and 1871 can be due to advances in the healing art, except to a minor extent.

We may still claim changes in the death-rate as representing the direction of changes in the general health, though they may not be proportionate in amount. Owing to changes in the position of boundaries and institutions we have to proceed cautiously in using figures, but we are in a position to compare death-rates in the Manchester Township, and in Greater Manchester, which we will take as meaning the three Unions of Manchester, Chorlton, and Prestwich. The figures are :—

Annual Death Rates in the Manchester Township per 1,000 *Inhabitants.*

1838–40	1841–50	1851–60	1891–1900	1901–1910
35·8	33·3	31·6	29·6	25·24

If we consider that the population in 1838–40 was a normal one, while in 1901–1910 it consists of the poorest elements of the population, these figures must be regarded as truly remarkable. Per contra, it is to be remarked that the proportion of young children in the population is smaller in the later than in the earlier period. On the other side, however, we have the terrible mortality in common lodging-house populations, which is probably not much less than 80 per 1,000.

Annual Death Rates per 1,000 *Inhabitants in Greater Manchester.*

1871–75	1876–80	1881–85	1886–90
28·3	26·2	23·6	24·6
1891–95	1896–1900	1901–05	1906–10
23·6	22·7	20·1	17·7

It should be noted that from 1891–95 onward to 1904 the area to which the above figures relate is considerably smaller than that of the earlier years. The corrected figures from 1891 to 1906 would be lowered if the comparison were exact. In future the area will be nearly the same as that for which the above figures from 1871 to 1890 hold.

The percentage of reduction since 1871–75 is 37·4.

There has thus been a great advance in the physical well-being of this population. But the death-rate is still amongst the highest prevailing in great towns, though we are slowly moving upwards. Manchester, like other towns, exhibits an immense improvement as regards some diseases, more especially smallpox, enteric fever, and scarlet fever. There is also a decided improvement in respect of whooping cough. The result must be a considerable improvement in the chest diseases of infancy.

Manchester, however, is still conspicuous for its high mortality, and it is especially conspicuous for its excessive death-rates from phthisis, from pneumonia, from bronchitis, and from heart disease. All forms of septic disease are unduly prevalent. There is also excessive mortality from measles.

In the course of a discussion of the causes of the high death-rates prevalent in Manchester and Salford, the Medical Officers

of Health gave in 1902 the following causes as in their opinion chiefly inducing the excess of mortality in this district :—

1. The crowding of houses on area, and their defective arrangement in past times. This is especially notable in the Manchester Townships, Hulme and Greengate.
2. The conservancy system of storing excreta. Admittedly requisite in the past, it is now a serious bar to an improved state of health.
3. The consumption of young life by the industries of these towns in the past, and to a less extent in the present, and to irregular and ill-paid labour.
4. The ignorance of the industrial female population in all that pertains to children,

and the following particulars of causes which had mainly contributed to the great reduction which had then occurred :—

Higher wages and more steady employment. Mutual assurance. Reduction of the hours of labour, and advance of the age of child labour. Cheaper food and clothing.

Better conditions of housing under recent building bye-laws. Improved water supply from Longdendale 1848 to 1884, Thirlmere 1886 to 1894.

Conversion of middens to pails in the City of Manchester, as then constituted, 1872 to 1880.

Improvements effected by the Unhealthy Dwellings Subcommittee, 1885 to 1901, and by the growth of the city.

The completion of a main drainage system.

The operations of the Manchester and Salford Acts from 1844, and of the Public Health Acts, especially of the Act of 1875.

The institution of Public Parks. Manchester and Salford inaugurated the possession of Public Parks by municipalities in 1848. These lie on the outer fringe, and will prove of immense service in the future.

Provision for the treatment of fevers in Monsall and Ladywell Hospitals, and for public disinfection at the Cleansing Depots in Oldham Road.

Voluntary effort and popular education by the Manchester and Salford Sanitary Association and by the Ladies' Health Society. Education by the Corporations.

Since 1902 the rate of diminution has been much accelerated. To this increased improvement unquestionably the housing

work of the Sanitary Committee has greatly contributed, and more recently the substitution of water-closets for pail-closets and middens. But there have been many other causes at work. Much attention has been devoted to the care of lying-in mothers, and of infants, a department of work which is susceptible of great extension. Much useful work has also been done in connection with tuberculosis and fevers.

It has become more apparent that the deposit in large amount of decomposing matters within the city is a most injurious nuisance. It cannot fail to accelerate the decomposition of foodstuffs, and may be largely responsible for the prevalence of septic disease.

The question, however, with which we are more immediately concerned is the effect on health of the large amount of smoke issuing from factory and house chimneys. It can scarce be doubted that our present customs as regards the use of coal are very expensive. The smoke is most injurious to vegetation in and near our large towns. The particles of soot as they light on leaves carry with them an oily matter and some sulphuric acid, and both must act injuriously on the breathing apparatus of the plant. Soot is found on the heather on the tops of the hills far away from factories. Trees in Manchester get their foliage late and shed it early. The loss in grass and other crops must be considerable. Buildings suffer in appearance, and mortar perishes. The windows of houses and factories are closed on account of the dirt which enters by the open window, and in any case the wash bill is considerably increased. Moreover, it thus happens that less attention is paid to cleanliness than is needful for health. The expert in consumption tells us that the open window is an absolute necessity in the treatment, and, therefore, in the prevention of consumption. Here, then, is a great injury inflicted on health by the prevalence of smoke in the atmosphere, which prevents people from opening their windows. But it is not only in the treatment of consumption that fresh air is needed, it is equally necessary for the rearing of healthy children, and for the treatment of fever generally. It is found in Nottingham that septic cases of scarlet fever do far better when treated in the open air.

Sunlight was shown first by Sir Arthur Downes, M.D., and subsequently by Koch, Delepine, Ransome, and others, to have a powerful destructive action on micro-organisms, and on their spores. Now, owing to the smoke blowing in on Manchester

from various directions, the city is deprived of light to an undue extent. Observations were collected for some years by Mr. Howarth, of Weston Park Museum, Sheffield, from a large number of centres as to the hours of bright sunshine enjoyed by them, and of these Manchester had generally the least or about the least. Here, then, one would think, is a ready means of determining whether smoke is injurious. We have, however, already seen that Manchester has a damp atmosphere, and that it has naturally a damp soil. The system of main drainage is proving inadequate in view of the rapid extension of the city, so that the subsoil is liable to be saturated with moisture at no great depth.

There must, thus, be an undue amount of moisture in the lower strata of the atmosphere, with consequent undue inclination to the formation of fogs. Such moisture will gather round any small particles of dust, whether of smoke or otherwise. Hence, if we desire to avoid fogs, we must take steps to reduce the amount of dust blowing about. It is also necessary on this, as on other accounts, to carry off the drainage of the city at a sufficient depth.

Nevertheless, although these influences may assist in the interception of sunshine, it cannot be doubted that the great interceptor is the smoke-cloud which is spread over the city.

We might, therefore, compare the number of hours of bright sunshine enjoyed in one place, and another with the mortality experienced from chest disease. It has always to be remembered, however, that smoke is only one of the influences producing a high rate of mortality, and we must also take into account the circumstance that centres of observation will give quite different numbers of hours of sunshine, according to their position in the localities concerned.

However, the facts, which, so far as other towns are concerned, I owe to the courtesy of the Medical Officers of Health, are as follows :—

Relative Mortality of Manchester and other great Towns from Chest Diseases. Also Record of Sunshine.

Year	Phthisis.						Bronchitis.						Pneumonia.						Sunshine—Hours.					
	Manchester	Birmingham	Leeds	Liverpool	London	Sheffield	Manchester	Birmingham	Leeds	Liverpool	London	Sheffield	Manchester	Birmingham	Leeds	Liverpool	London	Sheffield	Manchester	Birmingham	Leeds	Liverpool	London	Sheffield
1891	2·20	1·78	1·79	2·15	2·01	1·69	3·47	3·36	3·54	4·73	3·12	3·67	2·75	1·83	1·64	2·28	1·64	2·78	—	995	811	—	1222	—
1892	2·05	1·48	1·42	1·93	1·89	1·39	2·73	2·73	2·65	3·86	2·63	2·64	2·26	1·54	1·44	1·97	1·45	2·23	1038	1106	998	—	1277	—
1893	2·05	1·59	1·70	2·29	1·90	1·65	2·52	2·57	2·50	3·70	2·42	2·81	2·64	1·82	1·57	2·17	1·67	2·28	1227	1449	1223	—	1454	—
1894	1·97	1·28	1·49	1·97	1·74	1·48	2·00	2·22	1·93	2·83	1·80	2·20	1·98	1·39	1·29	1·85	1·23	1·69	955	993	1175	—	1052	—
1895	2·16	1·45	1·55	1·93	1·82	1·38	2·63	2·32	2·47	3·98	2·43	2·25	2·63	1·18	1·30	2·02	1·37	1·88	998	1241	1530	—	1227	—
1896	2·00	1·36	1·50	1·76	1·73	1·30	2·31	2·11	2·05	2·75	1·68	1·91	2·56	1·42	1·68	1·67	1·23	2·11	923	1000	1007	—	1016	—
1897	2·12	1·35	1·44	1·76	1·77	1·48	2·05	2·10	2·12	2·85	1·67	1·93	2·17	1·51	1·43	1·74	1·14	2·20	1112	1093	1256	—	1543	—
1898	1·95	1·41	1·39	1·73	1·79	1·26	1·81	—	1·72	2·70	1·74	1·53	2·19	—	1·31	2·06	1·22	1·62	1090	1066	1087	—	1415	—
1899	2·05	1·64	1·41	1·83	1·90	1·38	2·81	—	1·90	3·01	2·05	1·54	2·36	—	1·37	2·22	1·49	1·77	1241	1349	1300	—	1704	—
1900	2·09	1·63	1·41	1·80	1·79	1·43	2·99	—	1·94	2·98	1·93	1·68	2·50	—	1·72	2·11	1·60	1·88	1115	1084	1184	—	1506	—
1901	2·09	1·73	1·41	1·81	1·71	1·41	2·22	2·07	1·67	2·31	1·62	1·51	1·96	1·73	1·46	1·69	1·35	1·45	1192	1144	1520	—	1567	—
1902	2·08	1·65	1·31	1·81	1·65	1·18	2·44	1·91	1·77	2·62	1·71	1·52	1·98	1·62	1·40	1·98	1·47	1·45	928	1048	1203	—	1228	—
1903	1·85	1·45	1·27	1·65	1·62	1·36	1·87	1·73	1·45	2·29	1·15	1·71	1·87	1·48	1·26	1·68	1·28	1·58	1119	972	1333	—	1445	1216
1904	1·98	1·54	1·40	1·69	1·70	1·27	1·97	2·06	1·46	2·30	1·40	1·51	2·18	1·72	1·48	1·69	1·45	1·39	1031	1239	1289	—	1459	1325
1905	1·56	1·45	1·23	1·62	1·50	1·15	1·85	1·68	1·32	2·12	1·33	1·56	1·62	1·55	1·41	1·88	1·53	1·44	1005	1149	1280	—	1420	1432
1906	1·71	1·29	1·23	1·61	1·53	1·05	1·74	1·68	1·24	2·07	1·18	1·46	1·59	1·47	1·19	1·87	1·45	1·32	1069	1143	1251	—	1735	1438
1907	1·70	1·29	1·29	1·53	1·51	1·20	2·06	1·76	1·46	2·10	1·32	1·76	2·02	1·66	1·32	1·75	1·66	1·70	894	952	1167	—	1417	1428
1908	1·65	1·39	1·28	1·64	1·44	1·28	1·96	1·73	1·31	2·10	1·15	1·95	1·75	1·35	1·41	1·85	1·46	1·59	992	981	1056	1481	1634	1281
1909	1·70	1·44	1·14	1·40	1·44	1·17	2·00	1·77	1·36	2·30	1·35	1·32	1·72	1·46	1·29	1·96	1·68	1·54	999	1129	1124	1684	1641	1332
1910	1·49	1·25	1·04	1·36	1·28	1·01	1·59	1·51	1·11	1·74	1·12	1·26	1·40	1·33	1·23	1·73	1·49	1·52	982	1011	1276	1585	1380	—

If we adhere to the same centre of observation, the objection of varying position will not apply as between one year and another. Can we anticipate that there shall be any relation between the total hours of sunshine recorded in a given year, and the death-rate in that year from all causes, or from infectious diseases ?

Now, what strikes us first of all is that diarrhœa is exceptionally fatal in summers of high temperature, and therefore generally yielding a high number of hours of bright sunshine. In such years there is a tendency for the death-rate to be high, both immediately from diarrhœa, and afterwards from the effects of broncho-pneumonia attacking weakened frames. We could only look with confidence then for this relation to exist where there are no obscure collections of filth which will be quickened into activity by heat, without any opportunity for destruction by sunshine of the germs bred in them. It is, in fact, a necessary antecedent to the favourable influence of a high amount of sunshine that we should have an absolutely clean city, which we cannot at present claim to have. However, the facts are as follows :—

Years	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901
Hours of Bright Sunshine	1038	1227	955	998	923	1112	1090	1240	1114	1192
Death Rate per 1000 ..	23·2	24·3	19·8	24·5	22	22·4	21·2	23·0	23·8	21·6

Years	1902	1903	1904	1905	1906	1907	1908	1909	1910
Hours of Bright Sunshine ..	928	1119	1031	1005	1069	894	992	999	982
Death Rate per 1000.. ..	20·0	19·5	20·9	18·7	19·9	18·7	18·8	18·4	16·9

It will be seen that there has been a continued tendency towards diminution in the death-rate, but that this shows no dependence, so far as these figures go, on any improvement in the condition of the atmosphere. On the contrary, the aggregate amount of bright sunshine recorded has been less in recent years than the average. It does not follow from this, however, that there has been no improvement in atmospheric conditions. There might, owing to the growth of population, be a greater aggregate interference with the transmission of light, and yet a lesser intensity of smoke at any one particular time, and, so far as fogs go, there appears to be evidence to this effect. As

we have seen, however, there are reasons why the aggregate amount of sunshine should not have represented, in the years under review, an aggregate influence hostile to infectious germs. We may, however, eliminate the diarrhœa season, and confine our attention solely to the last quarter of the year. When this is done we find that both the general mortality and the mortality from respiratory disease have declined in the fourth quarter, while there is no corresponding increase in the hours of bright sunshine.

City of Manchester.

Amount of sunshine registered in the fourth quarter of each year, together with death-rates from phthisis and respiratory diseases :—

	Sunshine.	Death Rates from Phthisis.	Death Rates from Respiratory Dis. other than Phthisis.
1891	63·00	2·02	6·54
1892	69·72	1·92	5·92
1893	99·38	2·11	6·63
1894	67·12	1·74	4·79
1895	76·08	2·03	5·38
1896	67·09	2·09	5·57
1897	118·26	1·83	4·41
1898	73·75	2·02	5·03
1899	115·65	1·98	5·60
1900	96·66	1·93	4·80
1901	74·33	2·14	5·44

	Sunshine.	Death Rates from Phthisis.	Death Rates from Respiratory Dis. other than Phthisis.
1902	52·59	2·07	4·30
1903	91·85	1·82	4·29
1904	79·29	1·76	4·68
1905	76·70	1·55	3·71
1906	71·12	1·64	3·76
1907	82·07	1·36	3·78
1908	101·93	1·62	3·50
1909	93·22	1·37	3·76
1910	95·03	1·63	4·05
Average 20 years	83·24	1·83	4·80

We may pursue another line of enquiry. Regarding the presence of smoke in a district as directly injurious to the lungs, we may review the death-rates due to different forms of pulmonary disease in different districts in the city, and note in which districts the average mortality over a number of years is highest. Here, however, we are confronted with a difficulty. In some districts the smoke is largely due to factory chimneys, in others chiefly to house fires, and, of the two, the latter may be the more injurious to the lungs from its greater nearness.

This review of chest diseases in districts is made in the Annual Report on the Health of Manchester for 1910, pages 101 to 106. It will there be seen that the death-rates from pulmonary disease follow more closely the social circumstances than the atmospheric conditions of districts. It thus appears that there are potent influences at work determining respiratory death-rates, other than the atmospheric. This conclusion, however, by no means disposes of the possibility that there may be a decided basal and fairly uniform effect on respiratory mortality due to smoke, which does not emerge in the course of these comparisons.

It is doubtful how much we can expect to gather from this line of enquiry. There are, however, facts which point very definitely to the injurious influence of smoke on the lungs. Those who are accustomed to follow the weekly course of mortality cannot fail to be struck with the manner in which the mortality from respiratory disease ascends during dense fogs of any duration. When the weekly deaths from phthisis and from other forms of respiratory disease are charted for a number of years, the duration of fogs being indicated by the breadth and height of the columns representing them, this relation is shown in a most unmistakable manner.

Charts not reproduced, but exhibited.

It is not possible to exhibit these effects in an aggregate curve, since the effects of successive fogs interfere. But if we select particular fogs and disregard those which go before, and those which follow, we obtain by addition aggregate figures which do not, indeed, separate off exactly the effects of the fogs selected, but in which these effects are in a measure made manifest.

The influence of fogs in raising the mortality from all forms of respiratory disease, but especially from pneumonia and bronchitis, is thus rendered quite manifest.

This is a phenomenon which all can appreciate, since the irritating and injurious results of a dense fog on the lungs of older persons is a matter of common experience.

What Does a Fog Imply?

The formation of mists and fogs is believed to be due to the deposit of moisture in a still cool atmosphere, on particles of dust or other particulate matter present in the atmosphere. They occur most frequently in November and December, when evaporation from the surface occurs at a temperature higher than that holding in the atmospheric strata immediately adjoining. The morning mist of rural districts indicates an atmosphere in which the particulate matter is fine, while as smoke collects in the atmosphere the fog passes through different phases—through haze, light yellow, dark yellow, and black. The denser fogs occur when the barometer is high, and there is almost no movement of the atmosphere.

In these circumstances the particles of carbon emitted in smoke may accumulate, even if the temperature be above saturation point, when they cause what is called " a dry fog."

If, however, the smoke fog be due to the substitution of carbon particles for fine dust or other particles occurring in mist, we have the more common condition of a damp fog.

Smoke, of course, contains all the elements arising in the course of combustion perfect and imperfect of coal. Of these the most injurious are probably the carbonaceous unburned matter, the sulphurous and sulphuric acids, and the oily matters found more especially in the smoke from cottage fires. It is not certain that the inhalation of carbonaceous matter to the extent to which it occurs from the atmosphere of towns is highly injurious. It is true the lungs of persons inhabiting towns become more or less charged with carbonaceous colouring matter. But it is doubtful whether this alone leads to serious impairment of function. On the other hand, besides carbonaceous matter, much fine siliceous dust is inhaled in towns, and it is likely that this is highly irritating, and is liable seriously to interfere with function.

On the other hand, fogs, especially damp fogs, interfere with the dispersal and diffusion of sulphurous and sulphuric acids, which are present in large amount, especially damp fogs in which the acid attaches itself to the particles of moisture, which in their turn attach to the particles of carbon. It is doubtless to this cause that we must attribute most of the irritation and of

the pulmonary congestion caused by fogs, as well as the increase in mortality which attends them.

But even in dry fogs some acid adheres to the carbon particles. The oily or hydrocarbon matter which is present in smoke, and which remains in the lower strata in fogs, may also be injurious, though probably not so directly. It may, however, to some extent narcotise the ciliary processes, in other words, the cleansing apparatus of the bronchi, and so permit more ready entrance to the carbon and acid.

Another factor of importance in fogs is the increase of micro-organisms which must then occur. Micro-organisms attach themselves to small particles of matter, and in fogs they must accumulate in large numbers. It is probable, therefore, that the diffusion of bronchitis, and other diseases finding entrance by the respiratory passages, is facilitated by fogs,

The Relation of Fogs to Respiratory Disease.

What now are the facts as regards fogs and respiratory disease.

In the record of the proceedings of the Manchester Field Naturalists' and Archæologists' Society, for the year 1892, is recorded the results of a research carried out for them on the condition of the atmosphere of Manchester and Salford. An extract is there given of observations carried out by John Dalton on fogs :—

These may be thus stated :—

		No. of Fogs.	
	1804–9	24	
	1810–14	20	
	1815–19	57	
	1820–24	52	Record incomplete.
Two Years	1825–27	49	

The distribution of these fogs was as follows :—

August.	Sept.	Oct.	Nov.	Dec.
6	3	16	42	70
Jan.	Feb.	March.	April.	May.
37	15	8	2	3

The record of our observations taken at Oldham Road since 1891 gives the following :—

Year.	Days of Fog.	Days of Haze.	Year.	Days of Fog.	Days of Haze.
1891	25	26	1901	34	35
1892	46	45	1902	21	24
1893	36	60	1903	12	18
1894	60	25	1904	37	10
1895	61	56	1905	27	8
1896	63	67	1906	20	25
1897	38	62	1907	22	22
1898	28	37	1908	21	23
1899	41	28	1909	28	7
1900	18	30	1910	12	4

It would appear from these records that the number of fogs was considerable as far back as the beginning of last century. As regards recent history it would appear that during the last twenty years there has been a clear though not steady reduction in the total production of fog and haze.

It has already been mentioned that when the fogs are charted out, and the number of deaths from phthisis and from other forms of respiratory disease shown beside them, an unmistakable rise in the death-rate occurs within a few days from the onset of the fog.

This fact comes out the most distinctly in detailed charts, in which also the increased effects of prolonged fogs are manifest. It is a matter of experience, though our records do not enable us to show this, that the increased mortality depends also on the intensity of the fog.

If now fogs occurred so that we should have a clear interval of six weeks between one fog and another, it would be possible to write down for each of six weeks preceding, and for each of six weeks following the fog, the number of deaths from phthisis, bronchitis, and pneumonia respectively, and then on adding the deaths, the influence of individual fogs would stand out conspicuously. This, however, is not the case, and it usually happens that fogs succeed each other at short intervals of time. Hence their effects overlap and to no small extent neutralise each other.

We have seen, however, that fogs have a very rapid effect on the death-rate, so that their influence will be seen to some extent in the same week as the fog occurred, and in the week following. The effect in these weeks should, therefore, be clearly demonstrable by addition. I have, therefore, had the deaths from each of these diseases taken out for each of six weeks preceding, and for each of six weeks following the fog.

We should expect that when death is due to respiratory disease set up by a fog it would occur most frequently after one to three weeks' illness, but that the effect of the fog would extend to some weeks beyond. When we add the deaths in weeks we should have no evidence of adverse influence up to the week in which the fog begins, while after that the number of deaths should rapidly increase.

The facts can only be clearly understood by a detailed table. But I can only give here the result of adding vertically the columns which in the case of phthisis relate to 105 fogs for 1891–1910, and in the case of pneumonia and bronchitis to 59 fogs for 1897 to 1910. There can, I think, be no question that the effects thus demonstrated are due to the smoke in the fog, and not merely to the occurrence of fog.

The added figures are as follows :—

Deaths from Phthisis in each of six weeks preceding and in each of six weeks containing or following a fog for the twenty years 1891-1910 *added, the fogs not being of longer duration than six days.*

Weeks Preceding Fog.

6	5	4	3	2	1
2192	2040	2049	2135	2161	2224

Weeks of Fog and Following.

1	2	3	4	5	6
2377	2468	2360	2339	2334	2399

It thus appears that there is an increase in deaths, greatest in the first three weeks, but continued into subsequent weeks. The greatest number of deaths is in the week after the fog.

Deaths from Pneumonia during weeks similarly disposed to fogs in the same manner for the years 1897 *to* 1910, *added.*

Weeks Preceding Fog.

6	5	4	3	2	1
1351	1389	1345	1442	1442	1494

Weeks of Fog and Following.

1	2	3	4	5	6
1573	1638	1657	1710	1631	1589

There is here a clearly marked influence on mortality ascribed to pneumonia, greatest in the fourth week following the fog and next greatest in the third week. The effect on pneumonia is clearer than that on phthisis, and its maximum intensity is differently disposed, as if time were required for the development of the pneumococcus and the course of the disease.

Deaths from Bronchitis during weeks similarly disposed for the years 1897 *to* 1910.

6	5	4	3	2	1
1317	1301	1330	1526	1479	1627
1	2	3	4	5	6
1808	1864	1848	1699	1729	1749

Here the maximum effect is manifested in the first three weeks following, the greatest effects being produced in the second week, as in phthisis. The increment observed in the different forms of respiratory disease before the occurrence of fog is due to the fact that the different fogs interfere from their proximity to each other. Thus, while the effect of the individual fog is diminished, the total effect in producing an increase of mortality becomes more conspicuous.

The increase in mortality from bronchitis, like the increase from phthisis, follows more closely on the fog than does that from pneumonia. The processes are probably different. In the case of phthisis and bronchitis fogs cause congestion, in the case of pneumonia they probably light up pneumonia. When the fogs are of longer duration than six days, the numbers are comparatively small. The following are figures for 1891 to 1905 relating to six fogs :—

Respiratory Disease other than Phthisis.

Before the Fogs.

6	5	4	3	2	1
304	312	289	355	363	389

During and after.

1	2	3	4	5	6
394	484	417	398	375	332

No effect is observable under phthisis

These fogs do, of course, interfere with and are interfered with by other fogs. The effect of fogs in producing mortality from respiratory disease is unmistakable.

Is the Harm Caused by Fog Confined to this Condition?

If we refer to the analyses given in the research already quoted, p. 86, we find that a large amount of blacks, and, at times, of sulphuric acid is found in samples of snow collected at intervals of 24 hours. This will, of course, be most liable to be the case when the atmospheric pressure is high, and the air still, under which conditions more blacks must fall, and sulphuric acid will tend least to be removed. It also appears from these analyses that a considerable amount of sulphuric acid may adhere to the blacks. We must infer that the injurious influences noted are not confined to fogs, but exist under other conditions. Probably they are most in evidence for the majority of the population in still, heavy conditions of the atmosphere. But the direct injury sustained from smoke is not confined to these states of the atmosphere. The windows of an office well known to me are level with the tops of neighbouring chimneys. Now that the cold weather has arrived, these send forth plenty of smoke all day, and when the south-west wind is blowing, this is driven against the windows, when the sulphuric acid is quite perceptible to the sense of smell. This must be the case with numerous other workers in the city.

To sum up, there is no doubt whatever that both directly and indirectly smoke causes serious injury to health, especially during the months of November, December, and January. This injury is manifested in an increased respiratory mortality.

The same influence, however, must affect the population in all still and heavy states of the atmosphere, though in lesser degree.

In addition, at all times, smoke injures the health of the Manchester population by cutting off the rays of sunlight which act injuriously on the micro-organisms of disease.

This injury is somewhat obscured by the unfinished stage to which the cleansing operations of the city have arrived, but exists, nevertheless, in a high degree.

In spite of the efforts of the Sanitary Committee the diminution of sunshine at the Oldham Road Station in Manchester is greater than in almost all other centres of population.

It is of vital interest to the health of Manchester that a great effort should be made to diminish still further the smoke and fog prevalent here.

The first and necessary step is by every possible means to diminish the emission of smoke.

To this end, the emission of smoke, under Section 91 of the Public Health Act, 1875, should be subject to cumulative penalties.

The second part of this section, dealing with the emission of smoke from chimneys other than those of a private dwelling-house, is, at present, of little value. The word "black" should be omitted. Progress will be very imperfect until the emission of smoke from the chimneys of private dwelling-houses in such quantities as to be a nuisance is included under Section 91.

In order that this may be possible, it will be of great advantage that gas shall be cheapened to the utmost practicable extent.

Nevertheless, it does not appear to be necessary to wait for this, since it is quite practicable to burn coke in the fireplaces of private houses.

In order, further, to reduce fog and mist to the lowest possible point, it is desirable that the main drainage scheme sanctioned by Parliament shall be carried out as soon as possible, so as to diminish the amount of water present in the subsoil, and thence evaporated into the atmosphere.

In other ways, also, these works would react beneficially on the public health.

Until the above objects are attained something might be effected in schools by the use of model fireplaces and by instruction in the best way of using fuel, since it is quite certain that reasonable skill in the household is just as necessary as it is at the factory furnace.

If we are to experience the full benefit of sunlight, it is a necessary preliminary that there should be no collections of fermenting material stored within the city, and that all surfaces should be rendered as accessible as possible to the direct rays of the sun.

It is difficult if not impossible to compare the effects of sunlight in different places, since we require not merely to know how much direct sunlight reaches one or another locality, but how much of this available sunlight is permitted by the structural arrangements of the locality to act for the benefit of the population.

Moreover, it is necessary to remember that the amount of sunshine or sunlight transmitted depends not merely on the quantity of carbon particles in the atmosphere, but also on the amount of cloud passing over it, and on the quantity of dust which the air contains. We are, thus, again reminded of the necessity of freeing the locality from collections which can give rise to abundance of dust. Nowhere is it more necessary than in this locality to keep one's eyes open and one's mouth shut. Much of the harm arising from the impure atmosphere might be averted if breathing were carried on only through the nostrils.

Ten minutes daily of breathing exercise carried on in the schools would effect wonders. The mouth-breather in Manchester and other large towns is at a much greater disadvantage than he is in the country, and it is thus important that adenoids in town children should be attended to.

SECOND DAY.

Wednesday, November 22nd.

At the second day's sitting of the Conference, Principal John W. Graham was in the chair.

The proceedings opened with the reading of a paper by Bailie W. B. Smith, (Glasgow) on the subject of "Domestic Smoke."

DOMESTIC SMOKE.

By W. B. SMITH, Glasgow.

In most cities and towns some of the smoke in the atmosphere is produced in the ordinary domestic fireplaces, the proportion of domestic smoke to factory smoke varying according to local industries and the season of the year.

In Glasgow last winter a smoke fog occurred when there had been for a day or two an atmosphere with little or no wind, and the air over the city contained the smoke that had been produced in the various buildings in the city, without any having been blown over from other districts. Under these conditions we were able to get a fair sample of the atmospheric pollutions produced in the city itself. A chemical analysis of the atmosphere under these conditions showed that the fog contained about four-fifths of smoke from domestic chimneys, and only about one-fifth from factory chimneys. Of course, in the summer-time, when fewer domestic fires are required, the proportions would be somewhat different, but at any time probably at least one-half of the impurity in our atmosphere comes from domestic chimneys.

Now, if we can get rid of the domestic smoke, we immediately solve the larger part of the smoke problem in cities ; and I believe that this may be accomplished without resorting to legislation of any kind, by supplying the public with smokeless fuels, both gaseous and solid, at reasonable prices.

To the use of gas I think we must look for the first improvement, because gas-works have been long established and their mains are laid through nearly all the streets and into all the houses of the working-classes and most of the houses of the middle and upper classes ; and if they can get gas supplied to them at a price somewhat comparable with coal, the convenience alone must induce many of them to use gas in preference to coal for heating and cooking.

Then the gas-works must supply some form of coal residue much better than the ordinary gas-works coke or char, and I am convinced that this is the line on which gas-works must conduct their business in the future. They must so alter their process of distillation of coal that they may get over a clean gas of fairly high calorific value, that need not have a high illuminating power, and that will leave a form of coke that can be burned in an ordinary domestic grate ; so that, at the same time, they will be making two products that will be in great demand—a cheap efficient gas for the up-to-date people who will use gas appliances, and a smokeless fuel that can be burned in the old-fashioned grate by those who meantime have a prejudice against using gas, or who cannot afford to buy or hire new grates and appliances. At the price this smokeless fuel could be sold at, there would be a considerable profit, that would go to lower the price of the gas.

I am surprised that gas-works managers are so slow to experiment in this direction. Probably each one is waiting on some other one to begin it.

Then there is another hindrance to progress to be got rid of, and that is the absurd and financially unsound method that many corporations have of charging gas at a higher price in order to make what they call a profit or surplus, which they take to relieve the rates. How any community can tolerate such a thing, one can hardly understand. In Manchester last year the Corporation took £50,000 from the Gas Department to the relief of rates. Had they allowed their Gas Department to charge its legitimate price, gas in Manchester would have been twopence-farthing lower than it was, and, instead of being

charged at 2s. 3d., it would only have been 2s. 0¾d. We, in Glasgow, do not take any surplus from either gas or electricity to the rates, but sell these commodities to the consumers at cost price.

This method of contributing to the rates does not, in reality, lower the rates, but only alters the incidence of taxation; it means that the householder who has fitted his house with gas appliances, and thus kept the atmosphere pure, is compelled to pay more in rates, whereas his next-door neighbour, who, by continuing to burn raw coal in the old-fashioned way, really pays less in rates while he is helping to poison the atmosphere for himself and the community. Unfortunately, this contribution is levied by many English local authorities.

The same bad system applies more or less to electricity. In Manchester last year you took £12,000 from the Electricity Department, and the same the year before, thereby penalising the manufacturers who are using electricity in place of steam.

At present electricity is doing a great deal towards the prevention of air pollution from works, because so many are adopting it now in place of steam power; but it has hardly had time to do much for domestic chimneys. Within the last year or so, great improvements have been made on the electric appliances for heating and cooking, especially in the direction of economy of current, and, as in many towns current for these purposes is sold at about 1d. per unit, it is likely to be largely adopted.

The Discussion.

Councillor Johnston (Manchester) referred to Bailie Smith's opinion that corporations ought not to take profits out of the gas department. He agreed that, in a sense, we should be wrong in doing that, if it really *was* profit. He believed that gas should be sold at as low a price as possible, so as to encourage its use to the largest possible extent and do away with the smoke nuisance. The community, however, was entitled to charge something to each department of the corporation who used the streets. The gas department, for instance, ought to pay something for way-leave through the streets, but that charge should be very much less than the sum taken by the Manchester Corporation in relief of rates from that department. The amount should be determined by the

committee, and one advantage would be that it would save payment of income-tax. It would become part of the expenses of the committee, and thus no payment of income-tax would be necessary. He did not believe in profit-making departments. They ought to supply what the corporation produced at the lowest possible rates, after all reasonable charges on income had been made. The tramways department did not pay anthing for the use of the streets, whereas the old tramway company paid £23,000 per year. That was the principle we ought to adopt in regard to all the departments using the streets. But we ought to sell corporation products at as low a rate as possible, especially gas, and the greater the sale, the less the cost of production would be.

Mr. T. C. Horsfall (Manchester) suggested that attention should be given to the possibilities of the Arnott grate, the invention of Dr. Neill Arnott. He used it in four rooms in his house, and had done so for 30 years. He was convinced as a result of long experience that it was a most economical grate and most successful in burning smoke. He had never met with any grate that could compare with it. Throughout Great Britain coal fires were used in an extremely stupid and unscientific manner. What was taking place in that very room, for instance? That fire (a coal fire) was radiating a certain amount of heat into the air. From every door and every window and every chink in the room cold air was coming in, and was pushing back into the chimney quantities of the air which was somewhat warmed by radiation. In the use of the Arnott grate he had got at the exact method of warming the air without this defect. To the bottom of the space between the grate proper and the casing he brought fresh air from outside the house by pipes under the floor. The air was warmed in the jacket, and came into the room, ascended and circled through the room, and was eventually taken up through the chimney. Three times as much advantage in ventilation was obtained by adopting that principle, even with gas fires, while to convert fireplaces to this system would enable the production of three times as much heat from a given quantity of fuel, and would thus mean a saving in the amount of coal

Councillor Smith (Bradford) urged that the public health was more important than gas profits, and that hitherto members of public authorities had not, in relation to the matter under consideration, sufficiently appreciated the great disabilities to the

health of the community which resulted from the pollution of the atmosphere.

Councillor W. T. Jackson (Manchester) said that the question of gas profits was very important from the standpoint of the price of gas. There might be something to be said for the principle enunciated by Councillor Johnston as regards payment for way-leave. He entirely agreed that no profit whatever for rate relief should be made out of any trading department of a corporation, especially a gas department. From the standpoint of rate relief it was a bungling policy financially. It either brought no relief, or it was unjust to one section of the community. For if all the people of the city were gas consumers, then there was no relief. If all the ratepayers were not gas consumers, it was obvious that one section was being relieved at the expense of another. The ratepayers would get far greater value from cheap services. The amount of capital invested in the gas undertaking in Manchester was £2,700,000. Half of that had been paid off by the operation of the sinking fund, and over three millions had been paid off out of the profits in relief of rates. They could readily imagine what effect this would have had on the price of gas, if they had not gone in for profits. He believed that gas could be supplied at the very most at 1s. 6d. per thousand feet instead of the 2s. 3d. they were now charging. They recognised this principle in regard to water, where they were not allowed to make a profit, it being recognised that water was an essential thing to the health of the community. The same thing really applied to gas. Water was supplied at actually less than cost price for manufacturing purposes, and they ought to approximate the price of gas as nearly as they could to the actual cost of production to the community.

Other delegates pointed out the risk run by the ratepayers in financing gas undertakings.

The Chairman then called upon Bailie Smith to reply to the discussion upon his paper. The latter said that he desired to point out that a Corporation was very well protected in regard to the debt or financial responsibility incurred in relation to outlay on gas undertakings. Certain amounts were set aside for sinking fund, depreciation, &c. If a gas works did not pay one year, the price of gas could be put up until the receipts were enough to cover any losses. As

regards the relative cost of coal and gas fires for domestic use, he would give them the result of a year's experiments in two domestic households, taking the price of gas at 1s. 11d. per thousand feet (the price charged in Glasgow), and of coal at 10½d. per hundredweight. Burning the fires the same number of hours per day, gas came to about 25 per cent. dearer, not allowing anything for the cost of sticks, or lighting, or the trouble of cleaning in the case of coal fires. Using the gas fires fewer hours a day, turning it off when its use was unnecessary, the cost came to about the same, or sometimes gas was a little less. In summer gas got the benefit, but, taking it over the whole year, he did not think that the cost of gas would be more than 10 per cent. dearer than that of coal, not allowing anything for the extra labour which was necessary in the case of coal, which he was inclined to think would pay the difference. As regards way-leaves, in Glasgow they would not consider paying for them. They supplied gas to districts beyond Glasgow, and they would have to pay way-leaves to authorities wherever their mains went.

The Chairman said he thought they were all much indebted to Councillor Smith for the statistics as to the relative cost of coal and gas fires. Taking into consideration, in regard to coal fires, the labour in the cleaning and the lighting of fires, and the cost of the provision of sticks, and the waste in letting the fire out, he thought there could be little doubt that in the end, at the prices he named for fuels, gas would be as cheap. The idea that the ratepayer ought to get a profit from gas was fallacious, inasmuch as the ratepayer and the consumer were generally the same.

AIR POLLUTION IN GLASGOW AND OTHER TOWNS IN SCOTLAND.

By PETER FYFE, Esq.,

CHIEF HEALTH INSPECTOR OF GLASGOW.

"The great majority of men," said Emerson, "unable to judge of any principle until its light falls on a fact, are not aware of the evil that is around them until they see it in some gross form." When they see the evil in all its grossness they begin to think, to bestir themselves, to stir up their neighbours, to hold meetings, pass resolutions, worry their member of Parliament, and keep worrying until a law is placed on the Statute Book giving adequate power and machinery to remove it. It is to exhibit again the greatness of the smoke evil—its evil effects on health and life—I am here to-day.

When we look over the literature of the past on this vital question of air pollution, and note the names of the brilliant men—surgeons, physicians, chemists, scientists in all branches of human knowledge, and also civic administrators—who have written and spoken upon it with apparently little effect, I admit a feeling akin to despair creeps into the mind. We know the heart of the nation is not yet really touched upon this question. Why is this? Have the terrible facts not yet been placed before the people in a light which is vivid enough, or is it that those who are revealing the facts and shedding the light upon them have not themselves, in this matter, "clean hands and a pure heart?" Are the facts by themselves enough? Is there not a want of ideas on the part of reformers and administrators?

It was the renowned chemist Liebig who wrote, "The attaching too high a value to mere facts is often a sign of a want of ideas." In this particular case I would convert the word "ideas" into "*ideals*." Before we can impress our neighbours with our facts we must have the ideal towards which we ourselves are striving with might and main. A true reformer *in re* a purer

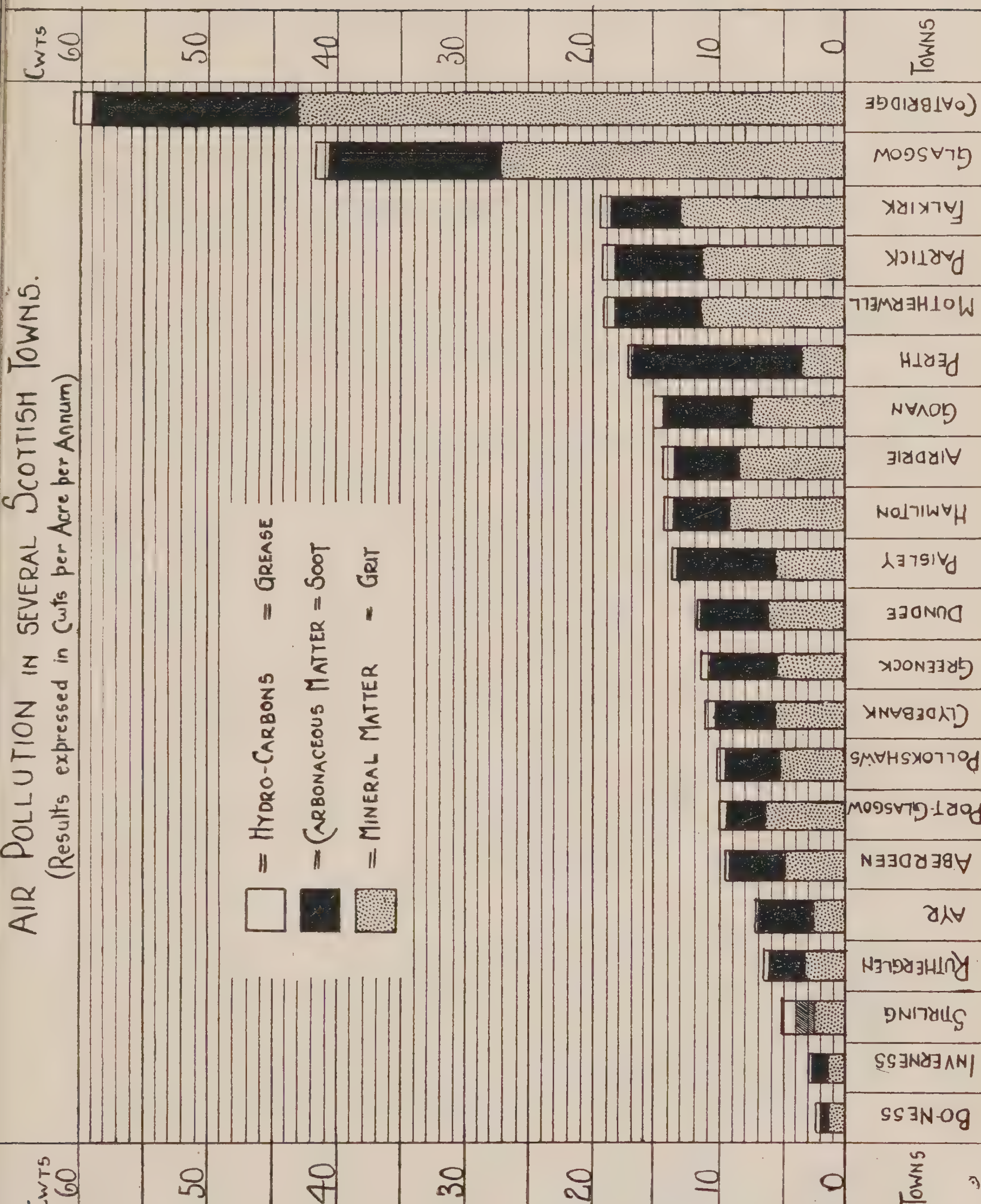
atmosphere must not himself defile it with smoke. If he does, or is known to do so, his " facts " will fall upon deaf ears.

Sir Henry Roscoe, M.P., in his presidential address to the Chemistry and Physics Section of the International Congress on Hygiene and Demography which was held in London 20 years ago, said truly : " Much, doubtless, can be done in preventing the output of smoke from factories and other places in which large quantities of coal are burnt, but after all the smoky atmosphere of our towns is caused chiefly by the thousands of domestic fires."

Now, at least 120 tons of solid matter, in the form of smoke particles or soot, are sent into Glasgow's atmosphere every winter day of 10 hours from her 200,000 active domestic chimneys. That may be taken as a " fact " calculated from many carefully conducted experiments by Mr. F. W. Harris, the Corporation chemist. The diagram before you (which I will explain later) shows that on every acre of ground in Glasgow 41·61 cwts. of solid matter fall in the course of a year (assuming the winter rate here shown to be maintained throughout the 12 months). Glasgow covers fully 12,000 acres, so that the total smut-fall for the four months of November, December, January, and February, would amount to 8,322 tons.

How much of this tremendous weight of smuts and dust is due to our domestic fires we do not know, and may never know ; but, in view of Mr. Harris's figures, drawn from experiments with domestic chimneys, it must be very great.

Now these are bald facts ; but they raised an idea in the minds of the special Corporation Committee dealing with this subject, and it was this : If our officials and employés in their various offices and places of employment are, under our authority, burning coal in open fireplaces, we ought to know of it, and, as an example to the citizens, try to put a stop to the practice. The idea fructified, and, in time, resulted in a lengthy return from all the head officials as to how they were warming their rooms, offices, stores, and workplaces. This further fructified into an order by the Committee and the Corporation upon all officials to adopt some smokeless method of heating in these places for the future. I commend this idea to all those who are in positions of authority. In my own office, not a particle of smoke is now made, and I have lost nothing in warmth, comfort, or convenience, and gained much in facility and cleanliness. Moreover, on the novel form of gas fire I have adopted, pieces of paper, matches, cigar ends, and other scraps, can be thrown and effectually burnt.


AIR POLLUTION IN SEVERAL SCOTTISH TOWNS.
(Results expressed in Cwts per Acre per Annum)
= HYDRO-CARBONS = GREASE
= CARBONACEOUS MATTER = SOOT
= MINERAL MATTER = GRIT
CWTS
60
50
40
30
20
10
0
TOWNS
COATBRIDGE
GLASGOW
FALKIRK
PARTICK
MOTHERWELL
PERTH
GOVAN
AIRDRIE
HAMILTON
PAISLEY
DUNDEE
GREENOCK
CLYDEBANK
POLLOKSHAWS
PORT-GLASGOW
ABERDEEN
AYR
RUTHERGLEN
STIRLING
INVERNESS
BO-NESS

AVERAGE AIR POLLUTION IN SEVERAL TOWNS IN SCOTLAND.

CWTS. PER ACRE PER ANNUM.

Town.	Mean Population, 1901-11.	Mineral Matter.	Carbonaceous Matter.	Hydro-Carbons.	Total.
Bo'ness..	10,086	1·35	·83	·09	2·27
Inverness	22,645	1·38	1·31	·27	2·96
Stirling..	19,801	2·52	2·50		5·02
Rutherglen	21,502	3·30	2·84	·56	6·71
Ayr	30,841	2·68	4·35	·25	7·28
Aberdeen	158,293	4·78	4·85	·24	9·87
Port Glasgow ..	17,303	6·55	2·90	·58	10·03
Pollokshaws ..	12,037	5·52	4·01	·62	10·15
Clydebank	29,224	5·76	4·49	·97	11·22
Greenock	72,025	5·80	5·08	·82	11·70
Dundee	163,994	6·17	5·53	·20	11·90
Paisley..	81,920	5·91	7·26	·62	13·79
Hamilton	35,709	9·25	4·37	·60	14·22
Airdrie..	23,338	8·61	4·81	·93	14·35
Govan	85,969	7·65	6·69	·65	14·99
Perth	34,923	3·58	13·34	·39	17·31
Motherwell	35,761	11·47	6·83	·97	19·27
Partick..	60,573	11·37	6·98	1·19	19·54
Falkirk..	31,424	12·99	5·77	·86	19·62
Glasgow	780,028	27·03	13·54	1·04	41·61
Coatbridge	40,139	42·96	15·97	1·66	60·59

Sanitary Chambers, Glasgow,
27th November, 1911.

Naturally the cost of such a fire, compared with a coal fire of equal warming power, has to be considered. I will deal with this aspect of the question towards the close of my paper. Meantime I desire to give you a survey of the atmospheric conditions which were found existing during two winter months of 1910-1911 in various towns throughout Scotland.

On the 10th of November, 1910, I sent letters to 20 sanitary inspectors, asking them to be good enough to cause atmospheric dust boxes to be put upon suitable roofs in their towns, about 30 to 35 feet above the ground level, and keep them there during December, 1910, and January, 1911. At the same time I forwarded a drawing showing the kind of box which was required, giving dimensions, so that all would be equal in style and size to the sixteen boxes I caused to be fixed at the same time on various roofs in Glasgow.

At the beginning of February, 1911, 36 boxes were returned to me to be examined by the Glasgow Corporation chemist, which, along with the 16 put up in the city, made 52 in all. In addition to these, 31 dust boxes were sent by eight inspectors to other public analysts, with instructions to have their contents analysed; so that in all, in order to yield us the information in the diagram before you, the contents of 83 boxes had to be carefully weighed and analysed.

As you will observe, the diagram shows the smut and dust fall in 20 different towns scattered throughout the country, from Inverness in the far north to Dundee and Bo'ness in the East, and Ayr and Greenock on the west. The variation shown in the amount of air pollution is very great; but when the character of the towns, their situation, and population are thoroughly understood, one is not surprised.

The little sea-coast town of Bo'ness on the Firth of Forth, with about 5,000 inhabitants, shows the least pollution. Two boxes were put out here, one on the roof of the Town Hall and one on the roof of the Hospital. When the contents of these are averaged, the total dust and smut fall during winter is found a rate per annum on each acre of its surface of only 2·27 cwts., of which 1·35 cwts. consist of mineral matter, ·83 cwt. of soot, and ·09 cwt. of tarry matter or grease.

As we would expect, our beautiful capital of the Highlands comes next in order of merit, although she has about 20,000 inhabitants. She still seems to have the atmosphere which Shakespeare speaks of in *Macbeth*, where he makes King Duncan remark, " The air nimbly and sweetly recommends itself unto our

gentle senses." Our diagram corroborates the great dramatist. This column shows a total fall of 2·96 cwts. per acre per annum on a winter fall, the mineral matter and the soot being in almost equal proportions.

From these two ideal atmospheres you will note the columns rise in pretty regular gradations until the manufacturing town of Falkirk is reached, with its 34,000 of a population, and great ironworks and foundries on its immediate northern boundary. Here the total smut and dust fall is found to be at the rate of 19·62 cwts. per acre per annum, or fully $6\frac{1}{2}$ times greater than that of Inverness. The Falkirk column indicates in a remarkable way the preponderating influence on a town's air of large manufactories. You will observe the proportion of grit or mineral matter as compared with the soot or carbonaceous matter—13 cwts. of the former, as against 5·77 cwts. of the latter—is very marked. The influence of ironworks and foundries on this town's atmosphere is even more marked when we go into details.

The Falkirk column is the average of the contents of five boxes put out in various parts, widely scattered. I take two of these, viz. : No. 3, put out on the top of the Burgh Buildings in the centre of the town ; and No. 4, put out on the top of the Oddfellows' Hall in the Grahamston district, which is nearest to the Carron Works and other foundries on the north side. In No. 3 the rate of total dust-fall is 6·48 cwts., and in No. 4, 43·49 cwts.—a wide difference. But a great divergence is also noted in the fall of the mineral proportions of these two samples. In the former, the proportion of fine grit was found to be 57·4 per cent., while in the latter it was 80 per cent.

The very reverse of this state of affairs is seen from the Perth column. Here we have the "Fair City," in Central Scotland, showing a total dust-fall of 17·31 cwts. per acre per annum, of which only $20\frac{1}{2}$ per cent. is composed of mineral or gritty matter. This shows that the great mass of her smoke comes from domestic fires, and comparatively little from such factory furnaces as may be within her borders.

I need not occupy time referring in detail to the columns between Inverness and Falkirk. They certainly show a certain amount of diversity, which a careful analysis of the character of the towns, their situation, their prevailing winds, and amount of rainfall would, I believe, fully explain.

I pass on to draw attention to the two high columns at the end of the diagram, which, as we look at them, suggest to us that Glasgow and Coatbridge may, with a few such in England, have

been the industrial towns of which Ruskin said in his " Stones of Venice " that they appeared to him as " clotted and coagulated spots of a dreadful mildew."

It is hardly credible that in these two towns there was an invisible fall of solid matter from the air during these two months of December and January to the extent of almost 7 cwts. on each acre in the former, and 10 cwts. in the latter. Yet such are the facts. Nay, in certain parts of these towns the dust-fall was much greater than is shown by the average figures. For instance, the box which was put up at the western end of Kinning Park, in Sussex Street, 50 feet from the ground level was found to contain soot and gritty matter representing a fall of 17 cwts. per acre in the two months ; while that placed on the top of the Theatre in the Main Street of Coatbridge, about 30 feet from the ground, showed a fall of no less than 21 cwts. per acre in that short period.

You will notice from the diagram that the mineral matter or grit which falls on each acre of Coatbridge is more than the total amount of grit, soot, and grease, which falls upon the acre in Glasgow. Doubtless this is the effect of the former town having a private Act of Parliament exempting all its manufacturers from prosecution under the law dealing with the black smoke nuisance ; consequently the manufacturing firms there are a law unto themselves, with the natural result that the brightest day in that town is hideous to the beholder. Cicero truly said, " The hope of impunity is a very great inducement for a man to commit wrong." There, each man has the certainty of impunity, and so a great wrong is daily and nightly committed on the entire 41,000 persons who compose the population of Coatbridge.

In Glasgow there is no hope of impunity for manufacturers, and this is reflected in the diagram, where you will note her grit-fall is 27 cwts. per acre per annum, against 43 cwts. in Coatbridge. Still, 27 cwts. per acre per annum is much too high, even for a winter figure. Her spring figure is less than half of this, the fall of grit or mineral matter being only 12·9 cwts. per acre per annum. This is the figure obtained from a series of similar experiments made in the March, April, and May of 1904.

Before this can be reduced much lower we must obtain further powers from Parliament. Surely it cannot be maintained that a law which permits an average of 11,000 to 12,000 tons of inorganic dust to be cast yearly into the air of a city like Glasgow is a righteous or satisfactory law. It has to be remembered that the tendency of steam boiler practice to-day is towards the use of

forced draught furnaces, in order to permit manufacturers to burn in their boilers the cheap class of fuel known as "gum" or "duff." Under the impetus given by powerful steam blasts or fans, great clouds of fine ash or dust are blown into the flues and up the chimney; and, while soot issuing in the form of black smoke may be gradually decreasing, we are being faced by an even greater pollution than black smoke—namely, fine ash and grit, which, being heavier than the carbonaceous particles, fall like rain on the areas contiguous to factories using this low-class fuel.

Last year Bradford was compelled by the growth of this form of nuisance to obtain fresh powers against black smoke issues from factory chimneys, and in Section 53 of her new Act, sub-section 4, obtained leave from Parliament to include such gritty particles as if their emission from any chimney were smoke arising from any furnace. Such a law, in face of what is now going on throughout the country, should be possessed by all Local Authorities in manufacturing districts, and the need for it is clearly set forth in the diagram before you. Every town in Great Britain and Ireland should possess powers similar to those which Bradford and Nottingham have to-day in respect of smoke from a manufacturer's chimney.

As to our domestic smoke, we are in a much worse position. We have no law but the moral law by which it may be suppressed, and when moral law is opposed to self-interest, as expressed in pounds, shillings, and pence, ethics is generally put on one side. We are all agreed that the thousands of household and office chimneys which daily pollute a town's atmosphere are a source of much dirt and discomfort every day—a source of "black fog" in winter on days when the air is still, and fatal at such times to those with respiratory ailments, and especially little children.

Science has shown us that 13½lbs. of solids, in the form of soot and hydrocarbons, are sent into the atmosphere with each million cubic feet of air and waste gases which ascend our domestic chimney. We know that the average domestic chimney sends into the air at least 10,000 cubic feet of such air and gases per hour, or 100,000 cubic feet in a day of 10 hours; so from ten such chimneys 13½lbs. of soot and tarry grease is a minimum issue for each day. If, therefore, you multiply this by the number of active chimneys in any town, and divide by ten, you arrive at a fair approximation of a town's daily aerial pollution from this source. In Glasgow we have certainly not less than 200,000 such active chimneys during the winter months, so that *then* our *daily*

discharge of soot and tarry substances into the atmosphere is fully 120 tons.

We are indebted to Principal Graham, of Dalton Hall College, Manchester, for the information that about 44 per cent. of her smoke is domestic ; and for the further statement that " it is a fairly safe conclusion that over the large towns of England and Scotland factory smoke and domestic smoke are each about equally responsible for the evil." This being so, it seems to me the conception of true citizenship must be raised to a higher level than it is to-day before we can discern even the dawn of that smokeless city we hope to behold.

A recent Oxford writer put it very well, though in a more general sense, when he said, " Everybody ought to apply to himself and others counsels of perfection. How ennobled would human nature be, if all men, in their several classes, and according to their several grades, social, intellectual, even moral, had each within him, an altar of perfection which he worshipped privately, and perhaps publicly too ! It would be heavenly to know that from every breast fragrant incense to the True, the Beautiful, the Good, rose up now and again."

I referred at the beginning of this paper to the need of " private worship " of the smokeless fire, and to the fact that in Glasgow the Corporation is now compelling all its officials, high and low, to install in their various rooms and offices that " altar of perfection "—namely, the modern gas fire.

I have perhaps the most modern one in Britain in my office. I had it fitted into my grate, where coal had previously been burnt. To obtain complete combustion of the gas and great radiancy, I installed a small electric fan, which is able to supply air for eight such fires at a cost of 6d. per day for current, or at the rate of three-farthings per day per fire for seven hours' burning. With the outside air at 49° Fah., I was able to maintain an equable temperature all over my room (containing 3,800 cubic feet of space) of 62° Fah. for seven hours for 6d. for gas, the consumption being at the rate of 37 cubic feet of gas per hour, or 259 cubic feet for the seven hours.

The air removed by way of the chimney was 10,560 cubic feet, thus giving very ample ventilation.

The total cost was therefore 6¾d. from 10 a.m. until 5 p.m., the gas costing 23 pence per 1,000 feet.

In a room of the same size, 65lbs. of coal were consumed in the same time in order to keep it comfortable. On account, however, of the excessive draught up the chimney—amounting in this case

to 18,480 cubic feet per hour—it was impossible to maintain an equable temperature throughout this room. We had the experience which has so often been referred to in connection with coal fires—namely, that the air of the room, being practically changed five times per hour, left the distant parts cold, while the parts nearer the fire were too hot. I am satisfied, however, that about 65lbs. of coal is required during a seven-hours' day, in a room of this size, to produce the comfortable effect which was obtained by the consumption of 259 cubic feet of gas in the new fire. At 10½d. per bag of one hundredweight, 65lbs. of coal costs 6d., so that, as far as cost is concerned, there is only three-farthings per day in favour of the coal fire as against the one I am using.

Anticipating criticism, I may say that the gas fire I am speaking of admits of cooking being done and water being boiled upon it. It will be seen, therefore, we are approaching the period when the advocates for the burning of raw coal in dwelling-houses will have the last and strongest prop withdrawn from under them, namely, the economic one. This prop, and this alone, prevents us going forward for legal powers against what Dr. Siemens called "our present barbaric methods."

Meantime the Smoke Abatement League, while watching carefully and anxiously the progress of gas and electric heating, and encouraging such methods wherever it can, both by example and precept, has a mighty task before it in educating the people to appreciate the direful effects of smoke upon the atmosphere of towns, from manufacturers' chimneys, which without doubt could be remedied if the law were amended, and made universally applicable over the whole country.

The Discussion.

Mr. Kershaw (Liverpool), after congratulating the Conference on the paper which had just been read, said that he would like a little more information from Mr. Fyfe as to the construction of the boxes he had referred to. It appeared to be a practical and cheap way of handling soot fall. But in Waterloo, near Liverpool, if they exposed the boxes in that way, they would have a great deal of dust and bits blown out in a very short time. On a hot day the boxes would be all right, but on cold, windy days half of their contents would be blown away.

Replying to Mr. Kershaw, Mr. FYFE said that the boxes, as stated in his paper, were all made similarly, one foot square and one foot deep. All these boxes were placed about the same height in the buildings. Whatever may have been lost by rainfall or storm, he could not tell. They had not taken the prevailing winds in the different towns; he was leaving that for some scientist who, he hoped, would be able to make the investigation more exactly than he did. Anyhow, in every place the boxes were the same and at about the same height, and, knowing the towns, one would say that the results shown in the diagram presented a remarkable view of the relative state of air pollution in them. Coatbridge they knew to be the worst; Glasgow they suspected to be second; they did not know where the third would be.

A delegate asked a question in reference to Perth. Mr. Fyfe told them in his paper that the fall was equal to 17·31 cwts. per acre. What he wanted to find out was this: If the supposition was that gas fires had a great superiority, in regard to the purity of the air, over coal fires, how did it come about that in a place like Perth, where there was, he supposed, as much gas cooking as in any place in the British Islands, there was about 17 cwts. per acre coming from the chimneys?

Mr. CUMMING, Chief Health Inspector of Perth, answering questions in regard to that town, said he thought the relatively large amount collected in the boxes there was due to the prevailing winds in Perth. It was in the centre of Scotland; Glasgow and Coatbridge were nearer the sea coast. The winds for the most part passed over Perth, which was situated in the middle of the hills, and this allowed a gentle rain of soot from the domestic smoke to fall into the boxes.

Mr. HORSFALL thought that the collecting boxes should be made about two feet deep. He knew from experience with a rain gauge that snow never blew out of a box 18 inches deep, and about 10 inches in diameter.

Alderman BURTON (Warrington) said that he was rather surprised about Coatbridge. He supposed that the smoke was produced by the operations of the furnaces, but, if puddling furnaces came within the operations of the Act dealing with smoke nuisances, he would like to know how it was that there was so much smoke produced at Coatbridge. Personally, he did not see any need at all for smoke to be produced from the production of steel.

Mr. Fyfe, answering the last speaker, said that Coatbridge had a special Act of its own, exempting the manufacturers from the consequences of their misdoing. They could make as much smoke as they liked. That was the reason.

Provost Davidson said that coming from Coatbridge, he should like to say a word or two to dispossess their minds as to the terrible state of affairs there, where it is quite a common saying that people like to see the smoke so long as it means business. It was one of the healthiest of towns, and he found the conditions there very enjoyable. Sometimes the smoke was very annoying, but they were very good-hearted people, and a great volume of trade was being done. He was whole-hearted in support of the purification of the air from smoke. The iron manufacturers in Coatbridge were beginning to see that there was some substitute for the fuels they had been in the habit of using, and he hoped that information from these meetings of the League would be beneficial to the manufacturers of iron and steel. With regard to steel works and puddling furnaces, whereas steel could be made without smoke, puddling furnaces did make smoke; and to prohibit the making of smoke would prohibit the making of puddled iron. With regard to the accuracy of the boxes for collecting the fall, he should say, especially in the case of snow, that they were absolutely useless. He attached very little value to the results obtained. They did not really corroborate what had been said about the enormous quantity of soot and dirt that existed, for if all they had heard were true, they would have contained very much more than they did, which was little more than an inch.

Mr. Fyfe (replying to the discussion) denied having said that the investigation with the boxes was scientifically correct. But however incorrect, the figures gave the proportion for the different towns.

Mr. Macaulay, Chief Smoke Inspector, Liverpool, mentioned that a little while ago he spent some time visiting a great works in Liège. In these works they manufactured steel rails, plates, &c., and puddled iron. Every furnace in the works was heated by gas. In the whole of the works about 7,000 men are employed, and there was no smoke whatever.

EFFECT OF SMOKE ON BOILER PLANT EFFICIENCY.

By G. B. STORIE, Esq., M.I.M.E.

In manufacturing centres it is not uncommon to hear advocates of smoke abatement referred to in terms other than complimentary, and the idea actually exists in some quarters that the views which they hold and expound on this important question are without foundation and harmful to the trade of the district in which they live. The author will endeavour to prove the fallacy of such statements by showing that the prevention of smoke, if carried out on proper lines, will, instead of being a hindrance to trade, effect economy, and return to the boiler owner value in the shape of a more efficient plant.

In looking at the constitution of the smoke abatement societies, it is gratifying to find that a considerable number of the largest users of steam in this country take part in their proceedings, and on the Continent wheresmoke abatement has made great progress, many of the principal societies consist almost entirely of steam users. The reason for this is not far to seek; steam users on the Continent are alive to the fact that nearly three-fourths of the total expenditure in producing power is incurred in the boiler-house, and they have found that attention to the scientific principles involved in the working of steam boilers is the means by which the highest boiler efficiency is obtained.

There are many channels of loss in steam-generating plants that are capable of considerable reduction, of these, the greatest, as a rule, emanates from the burning of the fuel in the boiler furnaces. This is the first and most important step in the production of steam, and as it is the source from which smoke originates, the author will devote his remarks almost entirely to that question. The paper which is intended in the main to plead with steam users for a better understanding regarding the scien-

tific principles involved in the working of steam boilers, is of a purely technical nature, at the same time it is hoped that the subject will be of sufficient interest to all the members of the Conference, to allow of this important question being thoroughly discussed.

Coal is used by all civilised nations, and it is the fuel above all others on which steam users most depend. Its principal constituents are carbon and hydrogen, and these contribute most largely to its economic value, as they combine with the oxygen of the air and give out heat. It also contains, in lesser quantities, oxygen, sulphur, nitrogen, and ash.

Carbon is perfectly consumed when it combines with 2·66 parts of oxygen to form carbonic acid gas, and partly consumed when it combines with one half the quantity of oxygen to form carbonic oxide gas and smoke. Hydrogen is the main element in the gas evolved from burning coal, and its combustion produces flame. In burning it combines with eight parts of oxygen from the air of the atmosphere and produces steam. When carbon is consumed to carbonic acid gas, it gives out 14,650 British thermal heat units* per pound. On the other hand, if it is consumed to carbonic oxide, a great loss of heat takes place and it only produces 4,400 British thermal heat units per pound. It is therefore of the utmost importance that as much carbonic acid as possible should be produced and the formation of carbonic oxide prevented.

The quantity of air admitted to the furnace per pound of fuel burned is the most important element in the combustion of coal and the distribution of heat. It is generally admitted that a sufficient supply of air should be provided for effecting the complete combustion of the combustible elements, the precise quantity however is subject to variation, according to circumstances.

Theoretically, 12lbs. or 150 cubic feet of air are required to effect the complete combustion of 1lb. of coal, but in the case of boilers working on chimney draught, it is usual to allow double that quantity to ensure combustion being complete, and prevent the formation of carbonic oxide in place of carbonic acid.

With thick fires and artificial draught created by means of fans, complete combustion would be obtained with as little as 18lbs. of air. This is due to the fact that when the fires are thick, the carbonic acid formed in the bottom of the fuel bed dissolves the

* The British thermal unit is the quantity of heat required to raise 1lb. of water through 1° Fah. when at a temperature of 39° Fah.

carbon higher up, and forms carbonic oxide, which is burned above the fires.

The intensity of the draught produced by a chimney is dependent on its height and the difference in density between the heated air within the chimney and the cold air without. Heat, therefore, is the means by which the air movement is brought about, and the efficiency of a chimney is measured by the amount of heat used to create the draught. With an atmospheric temperature of 62° Fah., the most efficient draught is obtained when the exit gases pass to the chimney at 552° Fah., as at this temperature their weight is only half the weight of the ingoing air. Atmospheric conditions have therefore a marked influence upon natural draught, and to obtain the best efficiency from the chimney, it is essential that the gases should leave the flues at a comparatively high temperature.

Artificial draught is independent of atmospheric conditions and may be produced by means of steam jets or by fans. The former are generally applied in the ash-pit for forcing in air which is made to pass upwards through the grates. The steam jet has also been used to deliver air above the fires in the form of finely-divided streams with a view to mixing it with the gases rising from the fuel bed. This system of producing draught is very costly, as a large amount of steam is used by the jets, and it also introduces a considerable quantity of water which has to be heated and carried up the chimney.

There are three systems of producing draught by means of fans : Forced, induced, and balanced. With forced draught air is forced through the fuel bed at a pressure above that of the atmosphere. This can be accomplished either by making the ash-pit air tight, and forcing the air into it at the required pressure, or by closing in the stoke hole and maintaining sufficient pressure therein to make good the quantity of air which passes into the ash-pits.

Induced draught is the system usually adopted in connection with land installations, and it is the nearest approach to chimney draught. A suction fan, which is placed near the bottom of the chimney, exhausts the gases through the furnaces and flues, and delivers them into the main flue or chimney.

Balanced draught has only recently been introduced, and is a combination of the two systems last named. The vacuum created by the suction fan is just sufficient to overcome the resistance due to the flues, &c., when the forcing or pressure fan is setting up the under-grate pressure to burn the required amount of coal.

As draught produced by means of fans is not affected by atmospheric conditions, it is independent of the temperature of the gases, and the opportunity is therefore presented of making use of the heat which is unavoidably wasted when chimney draught is employed.

Smoke is the result of incomplete combustion and is therefore an indication that fuel is being wasted. It may be produced :

(1) Immediately after fresh coal is thrown on the fire and discharged in the form of volatilised fuel which has escaped combustion.
(2) When the air supply is insufficient to burn the carbonic oxide formed above the fires.
(3) When the dissociated gases are suddenly cooled by an excess of air supply and pass off as carbon in the form of soot.

If a boiler is called upon to perform work greatly in excess of its rated capacity, the formation of smoke is almost inevitable, but, as a rule, hand stoking and insufficient draught are chiefly responsible for the production of smoke. Stoking by hand, however well performed, has many drawbacks. Each time the furnace door is opened to throw a fresh charge of coal on the grate, large volumes of cold air sweep into the furnace, cooling the fires as well as the boiler and its brickwork. Combustion is interfered with, and the gases pass off unburnt, with the result, that much smoke is formed. With hand stoking there is also the difficulty in keeping the grates well covered with fuel and the necessity that arises to poke the fires, which nearly always produces more or less smoke. Under such conditions, it is of course impossible to obtain the best results, and if the air supply is to be regulated, and improved combustion obtained, some better means of charging the furnaces with fuel must be adopted.

The author has endeavoured to show that, unless a sufficient supply of air is provided to effect complete combustion, carbonic oxide is formed with its resultant loss. When a chimney is constructed, its capacity is fixed once and for all, and in works where the nature of the trade calls for frequent extensions of the plant and a consequent increase in boiler power, the chimney becomes in time incapable of providing the quantity of air required to effect complete combustion. This is particularly noticeable where industries such as dyeing and paper-making are carried on. Enormous heat losses occur in some of those works, on account of the fuel not being properly consumed, and, as a rule, large volumes

of smoke are emitted from the chimneys. It is therefore important, where sudden demands for steam are made on the boilers, that there should be ample draught under control to supply sufficient air for combustion.

It has already been shown that air in excess of the theoretical quantity is required to ensure of combustion being complete. What the excess should be can only be determined from experiment, as the quantity of air required varies with the draught, temperature of air supply, and quality of the fuel. If the air be supplied in excess of that required, there is a two-fold loss; first, the excess air entering the furnace is heated by the burning fuel, thereby lowering the temperature of the mixture of gases; second, by increasing the volume and velocity, the final temperature of the gases is higher than would be the case if there was no excess of air, while the total amount of heat lost to the plant on account of the greater volume is much increased.

The only accurate method of ascertaining if combustion is satisfactory and the proper quantity of air is being admitted to the furnace is to analyse the flue gases. This is a comparatively simple operation and an apparatus suitable for the purpose can be procured at the cost of a few pounds. Such analysis gives a true record of the performance of the boiler and brings to light losses which could not otherwise be detected. About 19 per cent. of carbonic acid is the maximum that can be obtained with bituminous coal, this however is never obtained in practice, 16 per cent. being about the highest. Less carbonic acid recorded than the maximum indicates that air in excess of that required for combustion is being admitted to the furnaces, and the reduced carbonic acid represents the excess air. For example, with 14 per cent. carbonic acid the supply of air is 35 per cent. in excess, while 6 per cent. carbonic acid represents an excess of 216 per cent. It has already been pointed out that for the complete combustion of 1lb. of coal, 12lbs. of air is required, and this would give off 13lbs. of waste gases. The weight therefore with 14 per cent. carbonic acid would be increased from 13 to 16·9lbs. If the exit gases left the main flue at a temperature of 400° Fah., the loss would amount to 1,417 British thermal units. Assuming the coal to have a heat value of 13,500 British thermal units, 14 per cent. carbonic acid would represent a loss equal to 10 per cent. of the total heating value of the fuel, while 6 per cent. carbonic acid represents a loss of 24 per cent. These figures show the value of gas analysis and the necessity for careful regulation of the air supply to give the required quantity and no more at the right time

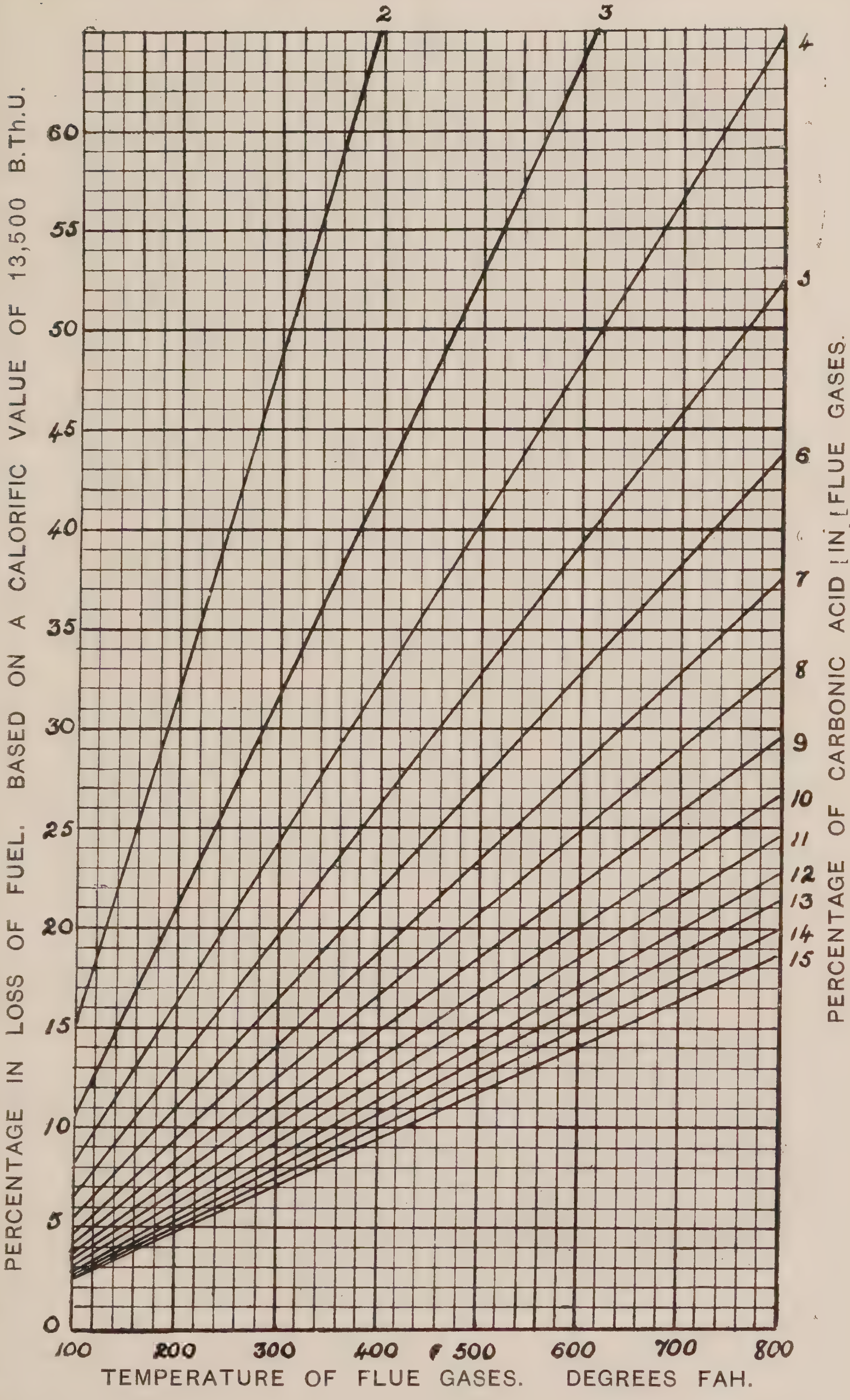
and place. Diagram 1 shows the loss in fuel, according to percentage of carbonic acid and temperature of exit gases.

It has been recognised for long that a supply of air over the fires is essential to ensure good combustion and prevent smoke, and nearly all furnace fronts are fitted with an arrangement whereby air can be admitted over the fires, as well as through the grates, when combustion is taking place. The usual method is to fit grids on the furnace doors with shutters, which can be adjusted to admit the required quantity of air. This is a good arrangement, provided the openings in the grid plates are made small enough to allow of the air being broken up into a series of fine streams, as better results are obtained when the air is introduced in this manner. The admitting of the air requires to be carefully performed, as an over supply would cool the fires and interfere with combustion. The management of the dampers in regulating the draught through the grates is of course a matter of great importance, but an intelligent fireman, guided by the analysis of the flue gases, can soon find out the correct positions of the damper to suit the various conditions of working. When a number of boilers are connected to the same chimney, the boiler dampers should be used for regulation purposes in preference to the damper in the main flue, as, owing to the varying conditions of the fires, what would be a proper supply of air for one boiler might be quite inadequate for another.

The accumulation of soot on the heating surfaces of boilers and feed-water heaters seriously affects their efficiency. Soot is one of the worst conductors of heat and it is generally deposited on the cooler plates of the boiler some distance away from the furnace, where the difference in temperature between the gases on the one side and the water on the other is low. Its presence greatly retards the transmission of heat from the hot gases to the water, and experiments have proved that the difference in efficiency produced by clean or soot-coated plates amounts to from 10 to 15 per cent. There is no mechanical means of removing the soot from the plates of the boiler, and this important work is usually left entirely in the hands of the flue cleaners, and is in most cases only performed annually to allow of the boiler being inspected. Feed-water heaters like the Green type are usually fitted with scrapers to remove the soot. These are worked by mechanical means and operate continuously when the plant is under steam.

The influence of soot and the necessity of frequent cleaning of the heating surfaces was clearly shown by Professor W. R. Johnson in his report on the trials of a cylindrical stationary

DIAGRAM I.—SHOWING LOSS IN FUEL ACCORDING TO PERCENTAGE OF CARBONIC ACID AND TEMPERATURE OF EXIT FLUE GASES.



boiler at the Navy Yard, Washington, made with the object of testing American coals. A large number of samples of coal were tried, and it was reported that there was a falling off in the daily performance of the smoky coals of from 20 to 30 per cent., and of about 9 per cent. of efficiency, accompanied by a rise of temperature in the chimney of from 65 to 100 degrees in the course of four days, consequent on the deposit of soot on the heat-absorbing surfaces of the boiler, and the reduction of conducting power.

There is further evidence from experiments made by M. S. Kestner on a feed-water heater of an experimental boiler at Thann. On the first day when the feed-water heater had been cleaned, the temperature of the water leaving it was 147° Fah. and 6·46lbs. of water was evaporated per pound of coal. Five days later a coating of soot had been allowed to gradually deposit on the pipes, when the temperature fell to 127° Fah., and the water evaporation to 6lbs. After the soot was removed, the temperature rose at once to 170° Fah., and the water evaporated to 6½lbs.

This evidence is sufficient to show the serious influence of soot when deposited on the heating surfaces of boilers and other apparatus used in the generation of steam, and it would repay steam users if they gave this important matter rather more attention than they have done in the past.

Smoke and incomplete combustion are inseparable; when combustion is improved, smoke is decreased, and there is a corresponding increase in the efficiency of the boiler on account of the carbon being more completely consumed. If therefore the formation of smoke is to be prevented, combustion must be complete, or in other words the fuel must be burned to the best advantage. To effect complete combustion, the following conditions are necessary :—

(1) The *proper* quantity of air must be supplied.
(2) The air and gases must be well mixed.
(3) The mixture of air and gases must take place at a high temperature to ensure that the carbon and the hydrogen will be completely burnt.

To obtain these conditions many contrivances have been invented and applied to steam boilers as an adjunct to the chimney, and some have met with a considerable amount of success. It is not, however, the author's intention to deal with these in the paper, rather, he prefers to confine his remarks to a system of draught entirely independent of the chimney which he has used and found to give satisfactory results, both as regards smoke

prevention and boiler economy, when arranged in conjunction with an apparatus for feeding the furnaces with fuel automatically.

The induced system whereby a partial vacuum is created in the furnaces and flues is the most natural method of applying artificial draught. There is no change required in the arrangement of the boilers from that which obtains when a chimney is used, and in most cases it is possible to arrange the fan directly at the exit of the main flue. Draught produced in this way is more flexible than that produced by a chimney, it is also more readily controlled and being purely mechanical it is entirely independent of atmospheric conditions. Artificial draught increases the temperature of the furnace, the rate of combustion, and the efficiency of the heating surface. More fuel can be burned per square foot of grate surface than with natural draught, and the maximum rate of combustion is obtained with the minimum quantity of air.

If the best results are to be secured through the application of induced draught, hand firing must be dispensed with, so that the frequent opening of the fire doors which interferes so much with combustion will be avoided, and a more uniform method of feeding the fuel obtained. Some form of mechanical stoker is therefore required, and from experience the author has found that a machine of the coking type is the most effective for the prevention of smoke when worked in conjunction with induced draught. The slow progress of the fuel towards the bridge, due to the motion of the fire bars, gives it an excellent and undisturbed opportunity for complete combustion, and the intense draught makes it possible to work with fires from 12in. to 16in. thick, which is an element in the increased efficiency. Further, with the coking system, the hydro-carbon gases from the fresh coal fired at the front of the furnace, which are so quickly distilled off by the heat, are ignited and burned in their passage over the glowing fire on the rest of the grate. If these, as has already been seen, were allowed to pass off unburnt, fuel would be lost and black smoke produced.

Induced draught has the effect of increasing the steaming capacity of boilers and 35lbs. of coal can be burned per square foot of grate surface economically, whereas with chimney draught 24lbs. is about the maximum. Two boilers, therefore, with induced draught, will generate about as much steam as three boilers with natural draught. In the case of existing plants where there is an insufficiency of steam, this is generally the most economical way of obtaining the additional boiler power required.

The principal reason for the increase in efficiency is due to the reduced supply of air required per pound of coal burned when the rate of combustion is increased, and owing to the higher rate of combustion the thicker fire is required, with the result that the air comes in contact with a greater amount of fuel and thoroughly scrubs it in passing through the bed. Further, the reduced area of the grate and the spaces between the fuel requires a higher velocity to secure the admittance of a given volume of air to the furnace, and this increased velocity calls for intenser draught. Much more intimate contact of the air and fuel is therefore obtained and the pressure required to effect this is seldom, if ever, created by a chimney.

It has already been shown that to produce draught by means of a chimney, a comparatively high temperature of the exit gases is absolutely necessary. This is one of the greatest sources of loss in the working of boilers, and in many cases as much as one fifth of the total heat in the fuel is absorbed in this way. On the other hand, draught produced by means of a fan is entirely independent of the temperature of the gases, and the heat which would have otherwise been wasted in producing chimney draught, can be usefully employed for other purposes. Opportunity is therefore presented to introduce air and water heaters, in addition to the feed-water heater usually installed with boilers, to abstract the heat from the waste gases. The number of purposes for which hot water and air, obtained in this way, could be used is unlimited, and there are few works where either one or the other would not be of value.

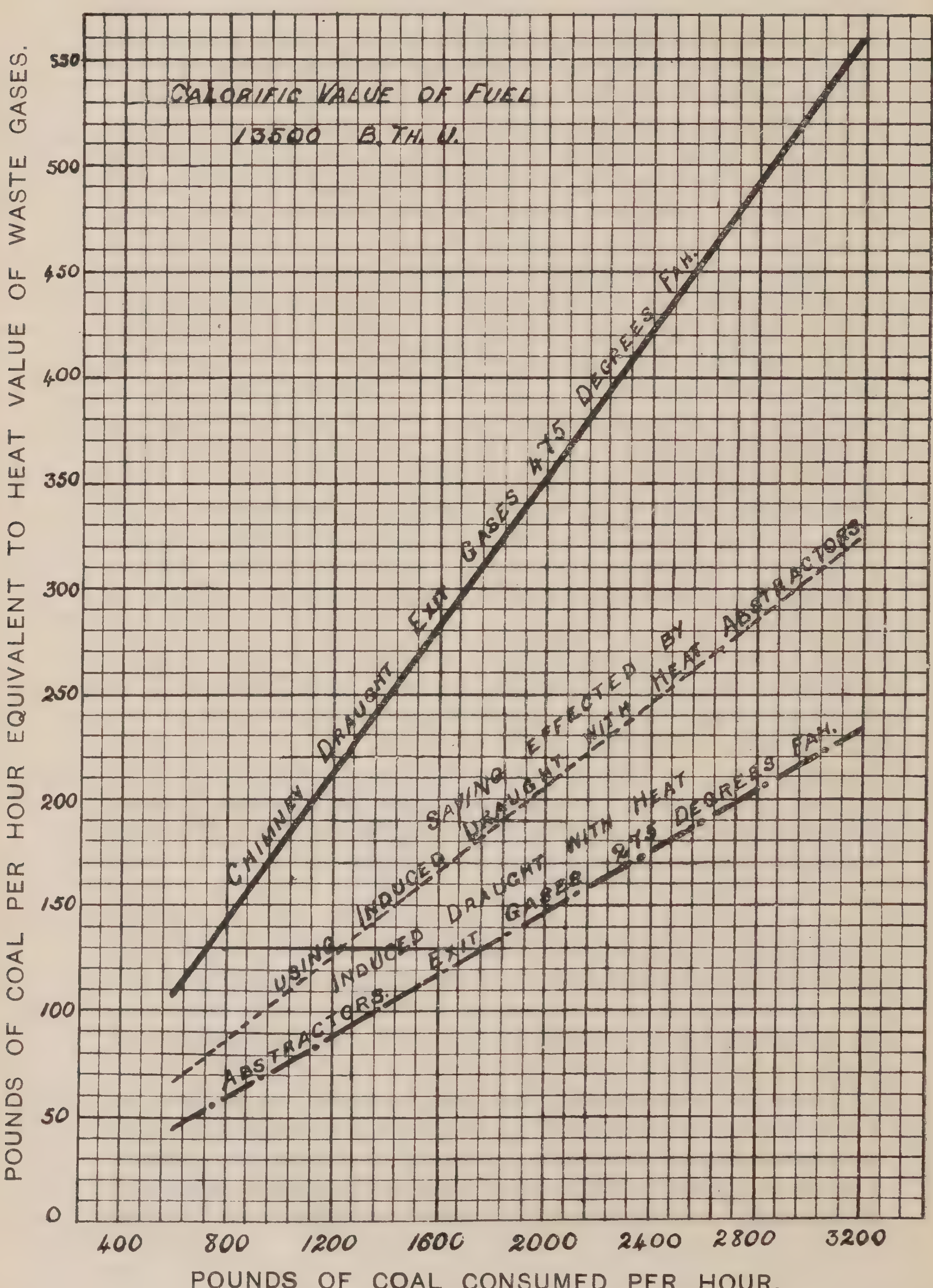
In many boiler installations, the air required for combustion is heated by the waste gases after they have left the boiler flues. The circulation of the air is effected by means of a fan placed at the outlet of the economiser chamber, which draws the gases through the tubes of a heater situated over the main flue at the back end of the boiler. The air for combustion which is drawn into the heater circulates outside the tubes through which the hot gases are passing on their way to the economiser. From the heater the hot air is conveyed in pipes to the furnace front, which is closed, and dampers are fitted to allow of the air being admitted both above and below the fires. The providing of this hot air which attains a temperature of about 300° Fah. ensures of a sufficiently high temperature being maintained during combustion in conjunction with intimate inter-mixture of the gases which as has already been seen, is of the first importance for the completion of combustion and the prevention of smoke. The Author has had

some years experience with a boiler plant arranged on this system and the results have been entirely satisfactory. On a carefully conducted trial, the plant showed an overall efficiency of 77 per cent., no smoke is produced, and the fan which at present delivers the waste gases into a chimney in the mill yard, is arranged in such a manner that it can be connected up to a steel chimney. This will be necessary at some future time, as the existing chimney will have to be removed to allow of buildings being extended. Owing to the absence of smoke, the new chimney will of course only require to be made slightly higher than the surrounding property. At the Hammersmith Central Power Station there is a similar arrangement to the one just described, with the exception that an additional heater is placed in the flue between the feed-water economiser and the fan. From this heater the air warmed by the waste gases after they have left the economiser is led in ducts to the heater over the main flue, to be further heated before it enters the furnaces. It is claimed for this two-stage system of air heating that the temperature of the air entering the high-temperature heater is such that the fall in temperature of the gases passing through the heater is greatly diminished, with the result that a higher feed-water temperature is obtained and the final temperature of the gases entering the fan are reduced to about 280° Fah.

The quantity of steam required to operate an induced draught plant of moderate size would not be more than $1\frac{1}{2}$ per cent. of the total steam evaporated, and with the smaller-sized plants, the consumption will seldom exceed 3 per cent. When the fan can be driven by ropes or belting through shafting from the main engine the cost of the power absorbed becomes even less, and in many cases it is hardly appreciable in the weekly coal bill. When air and water heaters are used, and the final temperature of the gases is reduced to about 275° Fah., the saving effected by the adoption of the fan draught over that created by a chimney is very marked. For purposes of comparison, Diagram 2 has been prepared to show the relative costs of producing natural and induced draught, also the saving effected by adopting the latter with heat abstractors, No allowance has been made for the increased efficiencies due to improved combustion.

Dyeworks, where sudden demands for steam are made upon the boilers, are usually looked upon as places where it is impossible to prevent smoke; this is not, however, the author's experience. Some time ago a firm of dyers had considerable trouble on account of the smoke emitted from their chimney, and after careful investi-

DIAGRAM 2.—SHOWING COST OF DRAUGHT PRODUCTION IN POUNDS OF COAL PER HOUR.



gation, it was decided to adopt induced draught. The chimney supplied air to the furnaces of three Lancashire boilers, two of which were used for generating steam, and in the third, water was boiled for the dye vats. In addition to the fan installation, mechanical stokers of the coking type were fitted to the steam boilers, and a water heater was installed in the main flue between the economiser used for heating the boiler-feed water and the fan. In this heater the water was boiled for the dye vats by heat abstracted from the waste gases, and the third boiler referred to was removed. The final temperature of the gases was reduced by this means from 510° Fah. to 290° Fah., and there was a clear saving of the whole of the coal used for firing the boiler in which the water was previously heated. The evaporation of the boilers was increased, and the smoke from the chimney entirely prevented.

Another case of a dyeworks, where the plant consisted of two Lancashire boilers and a fuel economiser, working on chimney draught, was not of sufficient capacity to produce the quantity of steam required in the works. The boilers were forced, and black smoke was emitted from the chimney almost continuously throughout the working day, the inhabitants of the district raised complaints and correspondence appeared in the local press on the matter. Eventually, it was decided to remodel the plant, and a new boiler and superheater were installed. The flues were enlarged, a coking stoker fitted, and a fan was put down to create draught on the induced system. The plant, with only the new boiler working, now supplies all the steam required, the machinery is kept at a constant speed, and the chimney, from a smoke point of view, is the best in the district, a slight blue haze being all that is discernible at the chimney top. A water heater for warming water for manufacturing purposes is now being installed in the main flue after the feed-water economiser, and when the plant is complete the owners anticipate that, in addition to the greatly improved conditions in the works on account of the increased steam supply, considerable economy will be effected in fuel.

Although the scope of the paper will not permit of further reference to works in which large quantities of steam are used for manufacturing purposes, and where, as a rule, great waste of heat takes place, both in connection with the generation of steam and its use, the author would like in passing to take the opportunity of stating that this waste, which is usually looked upon as a necessary evil, is almost wholly preventable, and in such

works there are opportunities of effecting economies seldom found elsewhere. He has no hesititaion in saying that when the plant is carefully arranged for making the best use of the available heat in the fuel and the steam produced therefrom, and also for reclaiming the rejected heat, it is possible to obtain efficiencies of over 80 per cent., including the engine.

To obtain the highest efficiency from any boiler, it must be worked to the best advantage and on economical lines. In the past too little importance has been attached to the boiler house, and notwithstanding the fact that nearly three-fourths of the total cost of producing power is expended in generating steam, it is looked upon as a place of minor importance when compared with the engine-room. The power user employs a skilled engineer at a good wage to take charge of his engine, and in many cases there is an assistant engineer as well, great care is exercised in the working of the engine, and the owner will fight for the last ounce to reduce its steam consumption. On the other hand, an ordinary labourer, provided he is capable of throwing coal on the fires and maintaining the steam pressure, is, as a rule, considered quite good enough to take charge of a battery of four boilers burning about £3,000 worth of fuel per annum. From an economic point of view this is an entirely erroneous idea, and an intelligent man, skilled in the art of firing and working of boilers, is one of the most valuable assets in the operating of a power plant. A boiler when at work requires constant and careful attention, and if the best results are to be obtained, the attendant must be capable of exercising a considerable amount of intelligence in the working of the plant. It has been suggested that suitable men for the purpose are difficult to find; probably they are, and this difficulty will remain, so long as there is no proper method of instructing men in the work, which is quite equal in importance to that performed by an engine attendant. It has been evident for long that some system of instructing firemen is required, lectures to firemen have been instituted in various parts of the country, these of course are useful, but something further is necessary, and in the Author's opinion nothing short of a complete course of training with practical demonstrations by an expert fireman will meet the case. The author is aware that in most cases the fireman is under the supervision of the engineer in charge of the engine, but this arrangement is not the one from which the best results might be expected, as often the engineer himself is short of the knowledge required, and his duties in the engineroom are such that he can only pay periodical visits to the boiler house in connection with

work which is of more than sufficient importance to call for a man capable of taking all responsibility, and devoting his full time to the operating of the steam generating portion of the power plant.

Every year a very large amount of coal is used in the generation of steam, estimated by some authorities at 250,000,000 tons and much of this is wasted through inefficiency. The price of coal fuel has increased almost two-fold within the last twenty-five years, and in his presidential address recently delivered before the British Association, Sir William Ramsey thought it necessary to draw attention to this waste and the rapid manner in which our coal supplies were diminishing. Everything points to the necessity for increased economy, and when it is said that the average efficiency of boilers working in this country alone is less than 60 per cent., there is surely ample room for improvement. An increase of 10 or 15 per cent. would represent a great over-all gain, and the author considers that there should be no difficulty in obtaining this, if power users would only realise the great importance attached to the working of steam boilers, as it is principally in the boiler house where the economy can be effected.

In conclusion the Author wishes to state that the scope of the paper has prevented him referring to many other important questions relating to the working of steam boilers, and although he has endeavoured to confine his remarks to matters relating purely to the furnace, he is just afraid that some of his smoke abatement friends will think that there has been a good deal in the paper about boiler efficiency and very little about smoke, but it is very difficult, if not impossible to write about smoke without writing considerably more about the efficiency of boilers, because if the efficiency is satisfactory, combustion must be perfect, and with perfect combustion there is no smoke.

APPENDIX TO THE PAPER READ BY G. B. STORIE, ESQ., M.I.M.E.

Considering that the greater number of boilers in this country are fired by hand, the author thinks that some further remarks on this question in addition to those already made in the paper might be of interest, as, although it is not possible to prevent smoke with this system of firing, it can, by exercising care, be abated.

The coking, the side firing, and the spreading systems are the three methods usually employed when boilers are fired by hand. In the coking system, the fuel is deposited on the dead plate where it is allowed to coke, and as combustion proceeds it is slowly pushed back in the direction of the bridge and replaced by another supply of fuel on the dead plate as before. With the side-firing system coal is fired alternately on each side of the grate. It is important with this method that one side of the fire should always be kept in a state of incandescence to allow of the gases rising off the green coal on the other side being ignited and burned, otherwise smoke would be produced. Less skill is required when the spreading system is used, as the fuel is spread over the whole surface of the grate. Satisfactory results are seldom obtained with this method, and more smoke is produced than with either of the other systems.

The coking system gives the best results both as regards smoke and efficiency, when the fires are thick and the draught good. This was clearly established at Wigan by the late Mr. Lavington Fletcher and others, who carried out an exhaustive series of boiler trials with the different systems of hand firing.

When the draught is light the boiler should be worked with thin fires made on the side-firing principle, and the whole of the grate surface should be kept covered with fuel of an even thickness to prevent the formation of air holes, otherwise air in excess would pass through the bed of

fuel on the grate and interfere with combustion. When the fuel is fed on to the grate in small amounts at frequent intervals its efficiency is considerably increased.

The regulation of the air supply through the dampers is, as has already been pointed out, a matter of great importance. It is of course impossible to lay down hard and fast rules, owing to the varying conditions of working, but in most cases it is better to commence with the damper just sufficiently open to give the proper quantity of air required to effect combustion, and it will be found that as clinker proceeds to form it will be necessary to gradually open the damper, until the time arrives when the fires have to be cleaned. There is a great inclination on the part of many firemen to work with the damper nearly wide open, but this is fatal to economy, and it is only done so that they can maintain the steam pressure without much labour. By carefully admitting air above the grate smoke can be greatly diminished. Some firemen leave the door slightly open immediately after firing, but if the furnace doors are fitted with grids or other arrangements for admitting air these should be used in preference, for the reason given earlier in the paper.

Poking the fires is one of the principal causes of smoke production, and although the author is aware that there are times when this operation cannot be avoided when boilers are fired by hand, it is a practice which should be discouraged as much as possible, as it has become almost habitual with many firemen, who have placed at their disposal in the stoke hole clumsy tools of various forms which they do not fail to use.

The effects of good and bad hand stoking are often very marked. Some years ago a prize competition in hand firing was carried out at Sheffield, and the difference between the best and worst man made a gain of 22 per cent. in evaporation and 18 per cent. in boiler efficiency with conditions exactly the same in each case.

A great deal can be done towards the diminishing of smoke from hand-fired boilers, and even in the case of varying loads, if there is sufficient draught under control to meet the maximum demand for steam, the author considers that the conditions from a smoke point of view in many works might be considerably improved by the exercise of care.

A number of years ago a series of trials of Newcastle and Welsh coals were carried out on behalf of the Admiralty

by Mr. T. W. Miller, and the following deductions from the report tabulated by the late Mr. D. K. Clark show a loss of efficiency of 17 per cent. due to incomplete combustion :—

SMOKE PREVENTED.

No.	Coal per foot of Grate per Hour.	Water evaporated per foot of Grate per Hour.	Water evaporated per pound of Coal.
	lbs.	cubic feet	lbs.
2	19·00	2·93	11·13
4	17·25	2·99	12·53
17	28·51	4·18	10·58
28	26·98	3·73	9·98
Means	21·69	3·46	11·05

DENSE SMOKE.

	lbs.	cubic feet	lbs.
1	21·15	2·62	8·94
3	21·00	2·91	10·00
18	29·53	3·94	9·63
30	31·56	3·58	8·19
Means	25·81	3·26	9·19

The following particulars relate to the graphic diagrams :

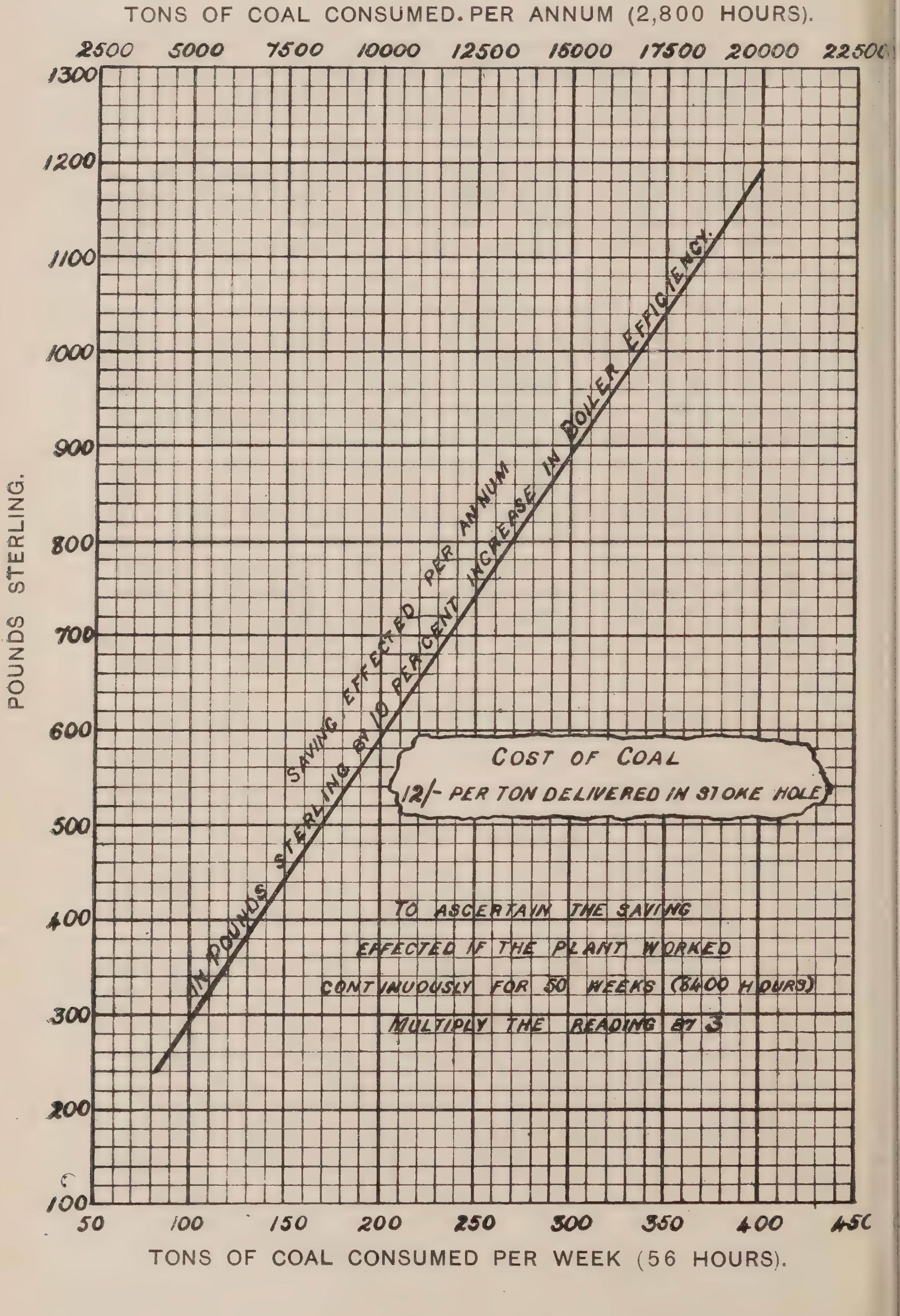
Diagram 1.—The diagonal lines represent the percentage of carbonic acid, the vertical lines the temperature of the flue gases above that of the atmosphere, and the loss in percentage of fuel is represented by the horizontal lines. Example: To ascertain the loss when the gases leave the flue at a temperature of 760° and contain 8 per cent. of carbonic acid, 760° – 60° (temperature of atmosphere) = 700°. Follow the vertical line at 700 until it intersects the diagonal line representing 8 per cent. carbonic acid, and, tracing the horizontal line to the left, read 29 per cent. loss of fuel.

Diagram 2.—The vertical lines represent the pounds of coal consumed by the boiler plant per hour, the horizontal lines the pounds of coal per hour equivalent to the heat value in British Thermal Units of the waste gases. The upper and lower diagonal lines represent the heat wasted by chimney and induced draught respectively, and the middle diagonal line

the saving effected over chimney draught by using induced draught with heat abstractors. Example: To find the cost in pounds of coal per hour in producing draught by means of a chimney for a plant consuming 2,000lbs. of coal per hour. Follow the vertical line at 2,000 until it intersects the upper diagonal line, and, tracing the horizontal line to the left, read 350lbs. The pounds of coal wasted when induced draught with heat abstractors is used, or the saving by its use over chimney draught, can be found in a similar manner.

Diagram 3.—The vertical lines represent tons of coal consumed by the plant per week and also per annum, the horizontal lines pounds sterling, and the diagonal line represents the saving effected in pounds sterling by increasing the boiler efficiency 10 per cent. Example: To find the saving effected by increasing the efficiency of a boiler plant using 300 tons of coal per week or 15,000 tons per year, 10 per cent. Follow the vertical line over 300 until it intersects the diagonal line, and, tracing the horizontal line to the left, read £900. To ascertain the saving effected when the plant is using the same quantity of coal per hour, but working continuously for 50 weeks, multiply the reading by 3. Taking the same example, the saving effected would amount to £2,700.

DIAGRAM 3.—SHOWING SAVING TO STEAM USER WHEN THE BOILER EFFICIENCY IS INCREASED 10 PER CENT.



THE GENERATION OF STEAM

ECONOMICALLY AND SMOKELESSLY

By James Bibby, M.Sc.

In this paper we will only deal with the smokeless production of power from coal as it affects the manufacturer.

The essential condition for smokelessness is that sufficient air at a suitable temperature be supplied to the fuel to ensure complete combustion, that is, that every particle of carbon and hydro-carbon in the coal shall leave the chimney in the form of carbon-dioxide and water vapour. The condition for economy is that no more air shall be employed than is necessary for complete combustion. We have, therefore, two apparently opposite conditions for ensuring smokelessness and economy; the one condition requires an ample supply of air and the other condition a restriction of air. The problem resolves itself into one of being able to obtain perfect combustion without using much more air than is theoretically necessary.

Without going into refinements, smoke is chiefly unburned particles of carbon and hydro-carbon; the carbon particles being solid and the hydro-carbons gaseous. Now smoke is produced when 1 per cent. of the carbon in the coal leaves the chimney unburned, and when 3 per cent. of the fuel goes up the chimney unconsumed there is dense black smoke.

The difficulty is to be sure that all the coal is burned without using too great a margin of air.

We will consider the case of the combustion of a quantity of coal containing 1lb. of carbon. To completely consume this, $11\frac{1}{2}$lbs. of air are required, and if any less air than this be used the result will be incomplete combustion and smoke. It is not only necessary that this quantity of air be supplied,

but it must be intimately mixed with the fuel at the right period, or complete combustion cannot take place, and if the appliance is not such as will ensure every particle of carbon being brought into contact with $11\frac{1}{2}$ times its weight of air, then smoke is produced. The only practical alternative is to use an excess of air to make sure that every particle of fuel receives at least its full proportion of air.

Given this condition for smokelessness, we will see the other effect of supplying an excess of air. When 1lb. of carbon is burned to carbon-dioxide, a definite quantity of heat is generated, about 14,400 British Thermal Units. Now this heat is given up to the gas in the flue, and the more gas there is per pound of fuel burned, or per unit of heat generated, the less will the temperature be raised. The flue gas will be the hottest when it is least in quantity, and, therefore, any air admitted beyond that theoretically necessary for combustion will reduce the temperature of the furnace. The more the excess air, the lower will be the temperature. It is even possible to introduce so much excess air that the temperature is reduced beyond the ignition point of the fuel, which would extinguish the fire. The maximum temperature attainable is produced when the fuel is burned with only sufficient air for complete combustion.

If carbon could be burned with only its correct amount of air, a temperature of about 4,800° Fah. would be produced, and 22 per cent. of the resultant gas would be carbon-dioxide, whereas if $1\frac{1}{2}$ times the amount of air necessary be admitted to the furnaces, then the possible temperature is 3,500° Fah.; with twice the amount, 2,500° Fah., and with three times the amount of air, 1,750° Fah. can only be reached.

The function of any boiler furnace is to generate heat in such a form that the largest quantity so generated can be readily transferred to the water.

Now the transference of heat through a given surface depends on the temperature of the gas, and a high temperature depends not only on the amount of air employed, but on the manner in which combustion takes place.

Carbon may be burned to either carbon-monoxide (CO) or carbon-dioxide (CO_2). It is burned to carbon-monoxide when the air is insufficient in quantity or not thoroughly mixed with the fuel. When 1lb. of carbon is burned to carbon-monoxide, 4,400 B.Th.U. of heat are liberated, and the temperature possible is only 2,700° Fah. If this carbon-monoxide at 2,700° Fah. is now burned to carbon-dioxide, another 10,000 B.Th.U. are generated and the temperature is raised to 4,800° Fah. The nearer we approximate to this

condition of converting or of burning the carbon-monoxide at a high temperature immediately to carbon-dioxide the better, for we shall then secure a rapid transfer of heat through the boiler plates or tubes. If, however, the carbon, after being burned to carbon-monoxide, is allowed to come in contact with the comparatively cold surfaces of the boiler plate it will be cooled, and will then, as it gets more air or better mixed with the air, start being burned to carbon-dioxide from a lower level of temperature. As an example, we may say that if carbon-monoxide travels down the flue of a Lancashire boiler, say a distance of 3 or 4 feet, its temperature will be lowered from 2,700° Fah. to, say, 1,300° Fah., and the maximum temperature obtainable from burning carbon-monoxide at 1,300° Fah. to carbon-dioxide is 4,000° Fah., and there cannot be so rapid a transfer of heat as would otherwise be the case.

The furnaces of a boiler should, therefore, be designed in such a way that the carbon in the coal is burned to carbon-dioxide as quickly and with as little air as possible. Any intermediate cooling-down stage whilst in the form of carbon-monoxide is detrimental to the efficiency of the plant.

It is not possible, after burning to carbon-monoxide, to immediately complete the burning to carbon-dioxide, because at high temperatures carbon-monoxide does not combine with oxygen to form carbon-dioxide. To accomplish this it would be necessary to have the gases during combustion under pressure, as in the case of combustion in a gas engine cylinder or in explosives; but from observation of the burning of coal in boilers the ideal conditions of immediate complete combustion can be fairly well approximated to, and by the proper regulation and distribution of the air and fuel far better results are possible than those usually obtained in boiler practice, where often considerable after-burning or late combustion takes place. It may be thought that since the total heat produced by completely burning a quantity of fuel is independent of the manner in which the chemical combinations take place, any ill effects of late combustion can be made good by increasing the heating surfaces or adding economisers and feed-water heaters until the flue gases are reduced to a low temperature. The objection to this is that the addition of heating surfaces and auxiliaries increases the prime cost and upkeep charges of the plant, and, owing to the extra obstructions, the draught is impeded; all tending to neutralise the otherwise good effects. The desideratum in steam-raising plants is to absorb as much as possible of the

heat generated in the boiler itself, and not depend to such a large extent as is often done on economisers. It must not be understood from this that the value of economisers is being depreciated. The duty of an economiser should only be to abstract from the furnace gas heat which it is not possible for the boiler to take up, owing to the water in the boiler being at a higher temperature than that at which the gas should enter the chimney. An economiser allows of advantage being taken of the comparatively low temperature of the feed water.

There is another important factor to be considered when the fuel is not completely burned at an early stage to carbon-dioxide. Whenever carbon-monoxide is present in a furnace, not only is there a deficiency or defective mixing of air to complete the burning, but there is also present an appreciable quantity of unburnt carbon and hydro-carbons. Now as carbon-monoxide and free carbon proceed through the boiler they are liable to be cooled by the heating surfaces to such an extent that any air then added will by preference combine with the carbon-monoxide and leave the carbon unburned and thus give off smoke. Failure to secure early complete combustion in boiler practice with bituminous coals produces smoke. With anthracite coals it produces grit, which is a nuisance second only to that of smoke.

Now steam-users are not usually satisfied in simply obtaining smokelessness and economy. In addition to these, as large a duty as possible is demanded from the plant, and in attempting with unsuitable appliances to obtain a large output smoke is made. We are therefore led to the consideration as to what are the conditions necessary for obtaining large duties without smoke.

When coal is first placed on the fire the hydro-carbons contained in it are vaporised, and this chills the fire. A considerable amount of heat is absorbed by the fuel before any heat can be generated, and unless the fire be hot enough and sufficient air be supplied at this point, the result will be smoke. If fuel is fed behind a fire at a greater rate than the heat in front of it is capable of volatilising, then the fire will go out. The duty of a furnace is therefore dependent on the temperature of combustion and the air supply. The aim should be to have as hot a fire as possible immediately in front of the dead fuel, and, as we have seen before, a high temperature is only possible when the combustion is completed at as early a stage as possible, and this is also the condition for economy.

Considerable progress has recently been made in the matter of obtaining this high temperature, and so increasing the speed at which the fire will ignite the dead fuel behind it.

We will now deal with the means adopted to secure high duty and economy smokelessly. There are appliances in the form of sprinkling stokers in which the coal is sprinkled regularly on to the furnace, and in which air is supplied beneath the furnace in such a manner that early complete combustion is secured, and, therefore, economy and smokelessness, but with all types of sprinkling stokers there is the following defect. When fine coal is sprinkled on the fire a fraction of the dust, or coke and ash from the dust, are liable to be carried away over the fire and emitted from the chimney as grit, lodging on the surrounding property and causing a nuisance. We will, therefore, not consider here this class of mechanical stoker and furnace, as, though it is satisfactory from the manufacturer's standpoint, it is not so in the eyes of the health authorities. This nuisance is most pronounced in the case of appliances which, in order to ensure good combustion, powder the coal and blow it into the furnace.

At present the only convenient means known of ensuring that there shall be neither smoke nor grits from bituminous coal is that in which the coal, instead of being sprinkled on the fire, is fed at the front of the grate, and the first process is one of coking the fuel. Bituminous coal contains a considerable portion (up to 20 per cent.) of volatile matter, and when heat is applied this volatile matter is separated from the solid or carbon portion. This volatile matter first of all becomes melted and then, as more heat is applied, becomes vaporised, and if sufficient heat and air are then present it will be ignited and consumed. If, however, there is insufficient heat or air, or both, instead of the gases being ignited and completely burned to carbon-dioxide and water vapour they are only partially burned, and smoke is produced.

When all the hydro-carbons have been driven off, the residue is coke. To thoroughly reduce bituminous coal to coke requires about 700° Fah., as well as sufficient air. Soon after the tarry matters are given off any hydrogen which may have been present in the coal will now combine with the oxygen in the air to form water vapour at about the same temperature. For the coke a temperature of about 1,000° Fah. is required to make it light up and combine with the oxygen in the air to form CO_2.

We will describe the type of coking stoker which has met the requirements of the manufacturer and the health authorities. In this machine the grate consists of a number

of hollow bars about $4\frac{1}{2}$in. wide, which are laid side by side to make up the grate width. The fronts of these bars are trumpet-shaped, and the portion which goes into the furnace is of U-shape, open at the top. Into these bars are loosely fitted a number of horizontal grids, the tops of which form the grate surface proper. A steam jet blowing in front of each bar forces air through the trumpet at a pressure sufficient to overcome the resistance of the fuel on the grate. The grids are so formed as to pick up the air forced in the bar and direct it as and where required in the furnace. The bars are made to travel to and fro in such a way that the fuel is carried forward, the majority of the bars going in together and returning independently to secure this action.

At the front of the furnace is superimposed, across the grate, a series of grids. These grids are stationary, but are supplied with air from the trough bars through an inclined scoop. Small coal is fed on to stationary grids from the hopper by means of two pushers to each flue, the strokes of which can be separately regulated. The fuel, as soon as it is pushed on to the stationary grids, becomes heated from the fire in front of it; the volatile constituents are driven off and ignited through sufficient air being supplied up the scoop. The fuel is then in a state of coke and is slowly pushed off these stationary grids by means of the dead fuel behind it, on to the moving grate, the motion of which carries it forward.

A leading feature of the furnace is to provide separately for the operations of coking and complete combustion. The air spaces are so proportioned that the correct amount of air is supplied for each stage. The coked fuel is completely burned by the time it reaches the end of the bars. The quantity of air forced into the bars and the speed of the bars are under control, and can be regulated to suit any duty up to the capacity of the furnace. Should the load be so light that the whole of the coked fuel is completely burned some distance before reaching the ends of the bars, air will escape through the bar ends and so cool the gases and lower the efficiency. The remedy for this is to reduce the rate of combustion by reducing the quantity of air forced in, and to lower the dampers. In some cases it would also be advisable to reduce the speed of the bars so as not to work with too thin a fire. On the other hand, should the duty be increased to such an extent that the coked fuel is not all consumed before reaching the end of the bars, a quantity will fall over into the back chamber. This is met by feeding more air into the bars and raising the dampers to increase the capacity.

It is a comparatively easy matter to observe what is taking place in the furnace, and a fireman has no difficulty in making the necessary regulations to secure economy and smokelessness under varying loads, and, as the proportion of air for coking is fixed, the speed of lighting up is practically automatic with the duty demanded up to the limit.

Such results have recently been achieved in the way of securing high temperature that ordinary bituminous slack can be made to light back at the rate of 4lbs. per foot width of grate per minute, with a draught of $\frac{1}{2}$in. water gauge in the furnace, as compared with the old limit of only $2\frac{1}{2}$lbs. per foot per minute. On an ordinary 8ft. Lancashire boiler this is equivalent to a consumption of 14 cwts. of coal per hour.

There is another point which must not be lost sight of. When a furnace depends for its air supply on the natural draught of the chimney or fans, it is found that no matter what care be taken in the feeding of the coal it will not burn regularly across the grate. Should one portion of the fire become thin, air will go through this at a greater rate than the other portions of the fire owing to the reduced resistance. The fire will become brighter at this place, and the fuel bed will become thinner still in consequence. When this happens (as it frequently does), we have a shortage of air where it is most required, at the thick portions of the fire, causing smoke; and a surplus of air where it is not required, lowering the temperature and the efficiency. This gives both the evils of bad combustion at the thick portion and an excess of air at the thin portion of the fire, a condition which is perhaps most pronounced in the case of locomotive firing, and is generally known as "pulling holes in the fire." Every good fireman recognises the desirability of avoiding this condition. With the type of machine we are considering this is well provided against, as, owing to the grate being divided into a number of independent longitudinal sections, only the determined amount of air can pass through any one section. Should one section become bare no more air will pass through, neither will the air pressure be reduced in the other sections, and the movement of the bars, together with the even distribution at the front of the furnace, corrects any such tendency. The effect is that almost complete combustion, with little excess of air, takes place at all parts of the grate.

The merits of any machine stoker and furnace depend on satisfying the following points:—

(1) A means for regulating the coal separately to each furnace so that the bed of fuel is level transversely.

(2) Independent provision for both the coking and full combustion processes, so that the correct proportion of air is supplied at the right periods for these processes and perfect combustion secured without requiring too great an excess of air.

(3) The furnace should be divided into a number of sections, and each section should be supplied separately with the correct amount of air for the quantity of fuel that it is intended to burn per section, so as to prevent short-circuiting of air.

(4) The bars should be given a horizontal motion in order to travel the fuel, and the speed should be capable of alteration to suit variations of load and classes of fuel.

(5) While the furnace is working there should be no opportunity for air to escape into the flues except through the furnace. A door should be fitted beneath the back of the furnace so as not to depend on the ash and clinker in the back chamber preventing air being drawn in.

(6) All the reduction gear should be machine-cut and in oil-tight cases, so that the machine will work under the adverse conditions found in many boiler-houses.

(7) An automatic means should be provided for discharging the ashes which fall through the grids into the trough bars, such as a triangular slide which periodically covers and uncovers ports in the bottom of the trough, and so allows the ashes to fall through into the flue.

From a large number of careful experiments it has been found that as a general rule, with a coking stoker of this type and bituminous coal, the steaming capacity of the boiler can be increased about 20 per cent. and the efficiency increased by from 5 to 10 per cent. over hand-firing. This result is being obtained without smoke, grits, or smuts, and in most instances firms who have adopted these plants have found that they can burn cheap fuel which could not be used to advantage by any other means.

Although the principles above have only been successfully applied within the last few years, considerable advance has already been made in clearing the atmosphere of many districts. As an example, in Liverpool many of the worst offenders, owing to the pressure brought to bear by the Chief Smoke Inspector, have modernised their plants, and not only have they satisfied the requirements of the authorities, but have found the results commercially beneficial.

Discussion on Mr. Bibby's Paper.

The Chairman opened the discussion by saying that Mr. Bibby was engineer for Messrs. Bibby, of Liverpool, who recently had a new installation of boiler plant and smokeless apparatus put in. Mr. Bibby had published a statement showing that by the new boiler plant and smokeless apparatus, he made a profit, after providing for new capital, of £65 per week, or £3,000 per year. A figure like that was fresh in their minds, and provided an answer to the extraordinary statement in the *Manchester Guardian's* leading article, that no considerable economy could ever be made by perfect combustion and smoke abatement.

Mr. C. E. Stromeyer (Manchester) said that he hoped nobody would think that he was opposed to the abatement of the smoke nuisance because of the line that he took. As Chief Engineer of the Manchester Steam Users' Association, he recalled the experiments carried out a great many years ago, involving trials of 400 different coals. They had a system of experiments, and the results had been a mine of information to subsequent investigators. That was over 40 years ago, and they had gone on till to-day, and yet they were not much further ahead. He simply mentioned these facts to show that he was not opposed to smoke abatement. As an engineer, he must confess to thinking that there was more enthusiasm for, than study of, smoke abatement. He thought there were other views to be brought forward, and, from an engineering point of view, there were several matters he would like to mention. The first thing required was to show how smoke could be got rid of, and all that they had got yet fell short of this. He held that that would always be the case unless they showed the people what was wanted. He had had to deal with a great many mechanical stokers. The usual result had been that they were very good to begin with, but that in the second or third year they gave trouble, and in the third or fourth year they got thrown out because they gave too much trouble. The hope to get them to work satisfactorily for quite a long time seemed to be unrealisable. The expense of keeping them in order was very heavy. The particular one mentioned in the paper did wonderful things. But the rule was that they had to blow steam in to keep the bars cool, and had to burn at a rapid rate. There was one very great disadvantage with regard to all forcing fires—the damage to the boilers. What he worked out theoretically

could be confirmed by practice. When you had intense fires you must have pure water in the boiler. Intense heat otherwise caused a lot of trouble in the boilers, giving rise to grooving or over-heating. Boilers which worked satisfactorily under ordinary conditions had, as soon as mechanical stokers had been adopted, become troublesome in one way or another. He hoped a mechanical stoker, combining all the necessary conditions, would be invented. The Conference, he must add, had been very interesting, and its proceedings deserved wide publicity.

A delegate then put the following question: In many industries, particularly the woollen industry, they had many manufacturers in the habit of using a very cheap class of coal and forced draught, the effect of which was that the small coke particles were rapidly carbonised without being properly consumed. It had also the effect of forcing these carbonised particles up the chimney, and they were deposited in the form of grit. Was it possible to get these particles deposited by a mechanical device, and was such a proceeding commercially profitable?

Mr. Edgar Mills (Manchester) said that Mr. Stromeyer's remarks had called attention to important factors in the engineering aspect of this question. They had shown the complicated nature of the process he dealt with. It was not only necessary to get the air, but to bring it into contact with the proper amount of carbon in the coal, and these conditions made certain demands. Hardly two factories were alike. They varied in locality, in coal, and in other respects, and themselves varied from day to day, and in many cases it might almost be said from minute to minute. It was, therefore, impossible for anyone to say that this or that apparatus was right without investigating the particular circumstances. It was not an easy matter to hit at all times, and under all circumstances, the happy medium between the minimum of air required for combustion and the maximum of air required to do away with smoke. He said for himself that, whenever he saw a chimney absolutely smokeless from morning till night, he was suspicious that it was produced at a loss of economy. This Association should not present a pistol at the manufacturer's head and say, "Thou shalt not produce smoke," at whatever cost it might mean. As to the mechanical stokers, he had been on the look-out for a mechanical stoker that should be as intelligent as the intelli-

gent fireman. The rate of pay of the fireman was ridiculous in regard to what was expected of him. If, combined with the operations of this Society, means to assist manufacturers could be found, it would be a very valuable addition to the work of the League. It was not sufficient to say, "You must not produce smoke"; a little more than that was required. They should go to the manufacturer, and give him a little guidance. It was not wise to adopt the principle that there was a standard to be imposed on all occasions, and the manufacturer needed a little protection, also, from the patentee who came round with a formidable list of testimonials, and said, "What I have done for these people I can do for you."

Mr. KERSHAW (Liverpool) said he had only one criticism to make on Mr. Bibby's paper. It was rather unfortunate to put forward the mechanical stoker as perfect. It was based on a scientifically unsound principle, the use of steam to obtain the necessary draught. As had been said there that day, the use of steam for forced draught meant introducing a considerable amount of air which had to be heated and carried up the chimney. Steam, moreover, had a wearing action of the steam jets. Though you started the system with a moderate amount of steam, the hole in the jet would enlarge, and in time it would be found that three or four times the amount of steam would be needed. He thought that mechanical stokers did reduce the smoke, but they had yet to await the perfect type.

Mr. MACAULAY (Liverpool) was very sorry to hear men like Mr. Stromeyer come here and say that it was almost impossible to produce smokelessness. He could take him to one place in Liverpool where he would find they used to use 25 tons of coal per day, and they now used 15 tons. They were doing twice the amount of work they were doing before. Smokelessness could go hand in hand with economy. The cost of fuel used to be £18 per day; now the cost of fuel was £6, and, more than that, the firm had one fire less than they used to have, and they had one boiler off. So far from holding a pistol at the heads of the manufacturers, in Liverpool the Medical Officer of Health inaugurated a series of classes at the University for the benefit of firemen and boiler attendants. These classes were well attended. The students, about 50 or 60 in number, were taken to the works of different manufacturers through-

out the city, and shown by practical demonstration the action of different kinds of furnaces with both hand-firing and mechanical devices. In the case of which he had spoken, the particular device at the works where the saving had taken place was still perfect after four years, and was working effectively and with the same economy.

Alderman Bennett (Warrington) thought that their ideal should be heat efficiency, and they required to convince manufacturers that they could do the thing right. He would like to say that they had one example in his own municipality, where they had succeeded in using the appliance and effected a very large economy. Crosfield's chimneys in the same town were famous all over the country as smokeless chimneys, and they claimed that they had made enormous savings, about £25,000 per year. Certainly, the chimneys were much the best in the town.

Mr. Storie (replying to the discussion) said that Mr. Stromeyer had referred to the Wigan trials, and he wished he had gone further. He found that Mr. Fletcher calculated on the Wigan trials that coals of South Lancashire and Cheshire districts could be burnt without smoke economically. With regard to stokers, he might say that he had eight boilers working on Rochdale Canal water, which was bad. All were fitted with coking stokers working in conjunction with induced draught. One boiler had been working for eight years. There had been practically no trouble either with the stokers or the boiler, with the exception that the fire bars had been replaced from time to time, which was only to be expected. He thought that Mr. Mills stated that a smokeless chimney was a wasteful one. He wished to say that it might be wasteful where excessive draught was admitted, but economy could be effected, and at the same time you could have a smokeless chimney. He had proved it over and over again.

Mr. Bibby (replying to the discussion) said that it was not working that killed a boiler, but worry. With hand-firing you got worry; with the mechanical stoker you got work, steady work, steady temperature, no variations, and he thought that the conditions with the mechanical stoker were more suitable. The boilers he spoke of had been working for four years, and they showed no signs of grooving or scouring. A gentleman had spoken about burning smudge without producing grits. The stokers were burning smudge

with coking stokers, and he believed the results were satisfactory and without grits. The whole thing was to get the smudge to coke. The volatile matter must be at least 20 per cent. If you got that, and provision for air in the coking process, there would be no grits. As to steam jets, the amount of steam used was $1\frac{5}{8}$ per cent., and there is, therefore, very little thermal loss due to that. With regard to the cost of stokers, supposing that they did wear out in two or three years, which they did not if used in a fair way, then it would mean in most cases spending £1,000 in the first year and saving £4,000 in coal bills. He could give Mr. Stromeyer about twenty such cases.

At this stage the Chairman asked Councillor Davies, of York, to give the Conference some account of the way in which they had dealt with the problems at Messrs. Rowntree's works at York.

Mr. Davies said that they had been faced with a great problem. They had got to a point where they had to produce more steam from a given set of boilers or put down new boiler plant. They had recently put down a big gas-producer plant and used gas engines, and they had also recently prepared in regard to electricity to take 1,000 kilowatts, enabling them to scrap the remaining steam engines. They still required a large amount of steam. They burned 30lbs. to 32lbs. of a very dusty Yorkshire coal per square foot, and could only do that by using a sprinkler type of stoker and induced draught. Using a very small, dusty type of coal, they got a large amount of grit, and they had to face that problem.

Mr. Davies went on to speak of a wash chamber which they had brought into use, in which the grit was allowed to settle and be washed out. Smoke from the flue was driven into the chamber by a fan. A scrubber was arranged at an angle of about 60°, in order that jets might spray down. The gas went up into the wooden chamber, but at a point it was reduced from what he might call a quick sprinting pace to a slow walking pace in going through the chamber. Hot water was sprayed in through nozzles, and they had cold water spraying on the scrubber. By these means it became possible to deposit the particles of grit, and they were removed from the chamber by the arrangement which he described. Mr. Davies said he would be glad to supply full

particulars of the boiler plant and of the washing chamber to any one who wished to have them.

In closing the Conference, the CHAIRMAN said they had had many opinions expressed on the burning aspects of the smoke problem. They had enough problems and difficulties to keep them going for a long time. It was pleasing to have had present at the Conference so many representatives from various parts of the country.

A vote of thanks to the Lord Mayor of Manchester for the use of the Lord Mayor's Parlour was heartily accorded by those present.

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Report of the Smoke Abatement Conference

held in the

TOWN HALL, MANCHESTER

November 4th, 5th & 6th, 1924

The

Smoke Abatement League

of

Great Britain

"Must Britons be condemned for ever
to wallow,
In filthy soot, noxious smoke, train oil
and tallow:
And their fumes for ever to swallow,
For with sparky soot, sniffs, and vapours
men have constant strife,
Those who are not burned to death are
smothered during life."

Winsor.

Smoke Abatement League of Great Britain

Report

of the

Smoke Abatement Conference

held at the

TOWN HALL, MANCHESTER
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Hon. Secretary:
C. ELLIOTT
33, Blackfriars Street
Manchester

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ADVERTISERS

Opening Session of the Conference

TUESDAY, NOVEMBER 4th, 1924.

Chairman:

Dr. R. VEITCH CLARK, M.A., M.B., Ch.B., D.P.H., LL.D., M.O.H. (Medical Officer of Health, Manchester)

accompanied by the Rt. Hon. the Lord Mayor of Manchester, Ald. W. T. JACKSON, J.P., and His Worship the Mayor of Salford, Ald. J. P. McDOUGALL, J.P.

LEGISLATION.

The CHAIRMAN, in opening the proceedings, said it was hardly necessary for him to say very much in relation to the smoke problem. Both at the opening of the Exhibition and at the Luncheon that morning they had had various aspects of the question put before them. He would, however, like to emphasise what he had had the opportunity of saying very shortly at the opening of the Exhibition, that, personally, he firmly believed that at any rate in well-administered areas repressive methods for the abatement of the smoke nuisance had reached approximately their maximum efficiency. The time had come when not only they, who were after all largely converted people, but the general public must realise, and were beginning really to realise, that the smoke problem was not solely a public health problem. It began as entirely a health question, but they knew now from the development of various types of by-products, and the proper manipulation of coal and similar fuels, that it was also a question of the economic well-being of the country. They were making a gross misuse of their resources in consuming raw coal, and could derive the power necessary for trade purposes, means of lighting, and all other uses to which coal was put, in a much more economical way than was generally done. It was significant both of the breadth of view of the Smoke Abatement League and also of the interest of the Conference, that the whole of those aspects of the question were represented in the papers and dis-

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cussions which were to form the gist of their meetings. The Smoke Abatement League was to be congratulated on getting together such an excellent programme, and he proposed not to stand between them and the real beginning of that programme any further.

The following Papers were then read :—

The Law against Smoke

by John W. Graham, Chairman of the Smoke Abatement League of Great Britain.

The Present Law.

By the Public Health Act of 1875, manufacturing smoke may be treated under one of two clauses, one which definitely forbids smoke which can be proved to be black, as a nuisance, and another which without limitation of colour, declares that every owner or fireman is to avoid smoke *as far as practicable.* This latter clause has been found to be unworkable in practice, and is never used ; for it leads to a dispute as to what is " practicable," in which expensive expert testimony is likely to be brought in. The London County Council vainly prosecuted the Lots Road Electric Station, and were cast in heavy costs of £300 because the magistrate declared that the smoke was proved to be grey.

Moreover, Section 334 says : " Nothing in this Act shall be construed to extend to mines of different descriptions, so as to interfere with or to obstruct the efficient working of the same ; nor to the smelting of ores or minerals, nor to the calcining, puddling and rolling of iron and other metals, nor to the conversion of pig iron into wrought iron, so as to obstruct or interfere with any of such processes respectively."

The last words show that the exemption for smoke in those processes does not extend beyond the necessities of the process. But it is extraordinarily difficult for an observer to know exactly how much is necessary.

In practice our smoke legislation is a dead letter, except in London and about seven provincial towns, Manchester, Glasgow, Sheffield, Bradford and Liverpool, and the two towns of Leicester and Nottingham where lace and hosiery have to be kept clean. There may be a few other places of which I have not heard. The fines are extremely low and usually run to about 30s. or £2, though it is possible to go higher, and a Sheffield firm was fined £34 lately.

The health committees and magistrates are often connected with the offenders socially or by family ties. "Well, we have to live with them," a magistrate said to me the other day.

In my opinion it is impossible to legislate against domestic smoke at present. It is not possible to make gas or electricity compulsory and universal yet. Any legislation against the smoke from the kitchen fire would have to allow at least ten minutes' smoke in the half-hour; and the quantity is so small from each chimney that there would be much disputing over it. The time is, however, close upon us when the result of the many processes of low temperature carbonisation will be universally accessible. When that has become established, legislation against all use of raw coal may become practicable and reasonable; at any rate, legislation against domestic smoke will be in order.

Recent History of the Movement.

In 1909, at a Smoke Conference collected at Sheffield, which met in the Town Hall, the Smoke Abatement League of Great Britain was founded, and produced a memorial which was presented to Mr. John Burns, at the Local Government Board, by 28 members of Parliament and members of corporations. It was plain that the permanent officials were unsympathetic, not wanting more work put upon them. The Local Government Board had previously refused us a conference with them. The memorial embodied the proposals which I will describe later on. Nineteen considerable municipalities, led by Glasgow, Liverpool and Manchester, signed the memorial. Nothing came of it at the time, except leading articles in several papers. The Ministry of Health, formerly the Local Government Board, has been a disappointment always.

Our next task was to draft a Bill. I spent a year over this, and communicated with 82 of the principal municipalities in the country, sending round to them successive drafts for criticism. We finally reached an agreed scheme, which may fairly be called "The Municipalities Bill." We obtained the approval of the London Coal Smoke Abatement Society, and Mr. Gordon Harvey attempted to have it introduced into the House of Commons as a private measure. A year passed without result; and finally Lord Newton offered his help in the House of Lords, where the Bill was read a first time in the Spring of 1914. It had been changed slightly in wording by that time from the first draft of 1912. Copies are in the room. The Government, thinking that something unofficial or unwise might be done, asked Lord Newton to withdraw the Bill, promising to appoint a Departmental Committee to look into the whole subject. As the prospects of the Bill as a private measure were poor, he and the League

agreed to this. A Departmental Committee was appointed and had a number of sittings under Mr. Rea, until it was adjourned *sine die* on the outbreak of war in August, 1914. With some difficulty it was resuscitated in 1920 under Lord Newton, saw a great many more witnesses, visited provincial centres, and issued an interim and, at the end of 1921, a final Report. The minutes of evidence are not published. It recommended the increase of fines, the standardising of the time allowed for making smoke, the provision of a central Department on the subject at the Ministry of Health, and an increase of the size of the areas dealing with the subject. These were all valuable and necessary proposals, but the Committee was so impressed by the manufacturers' statements from Sheffield and the Potteries, to the effect that smoke-making was essential to their business, that they gave way upon the crucial point of making smoke emission a definite offence, and recommended that the words " as far as practicable " should occur in the Act ; the onus of proving what was practicable being laid on the manufacturer.

But the effect of this is to carry the difficulty special to these two trades into the whole smoke-making of the country, and to raise the question of what is practicable, over every smoky boiler. The whole country must be dirty that Sheffield and the Potteries may go on as they are.

In lieu of the exemption clause, Section 334, there should be given an opportunity to any manufacturers asserting that smoke is necessary to their business, to appear before a Government expert Commission, which would be empowered to use the principle of the words " as far as practicable," and permit smoke for some processes for a specified number of years, say, two or three, awaiting improvement in technical methods in the future. The defence, " as far as practicable," should be carefully omitted from every other place in the Bill, and the sentence about taking into account the element of cost in abating smoke should be omitted. No doubt that would be taken into account very seriously by any Bench of which we have hitherto had any experience ; I think it not necessary to weight a public authority with this handicap under the Act. There is, in fact, hardly any capital expenditure on smokeless apparatus which does not in time amply repay the outlay if it succeeds.

The late Coalition and Conservative Governments have introduced two Bills in two successive years into the House of Lords, neither of which has been carried through. One can only be glad of their failure. They were compiled after consultation with the representatives of trade interests, and their result might be said to be smoke promotion rather than smoke prevention. They were " legislation by reference " to past Acts,

amending the Act of 1875 (for London, the 1891 Act) in various ways, and were severely criticised in the House of Lords in this sense. They actually extended the businesses that were exempted in Section 334, so as to include every process in the iron and steel trades. They avoided the appointing of any extra staff at the Board of Health as a Central Smoke Authority ; they extended the smoke areas to those of the County Councils and County Borough Councils ; they satisfactorily increased the fines ; and they made the plea that smoke was abolished " as far as practicable," " having regard to the cost involved " in abolishing it—a " defence in every case." This alone would discourage any Health Committee from prosecuting. Under these Governments there was no real intention effectually to clean the air which the people breathe. The Department shuns more work, the Treasury bars expenditure, and trade interests, whose representatives unfortunately take a short view, commanded many votes in the House of Commons.

The Labour Government introduced a third Bill in 1924. To our intense disappointment it was a small Bill on the lines of the other two, a departmental Bill. It contained however one improvement. Black smoke from boilers remains amenable to the present law. Smoke not black may offer the defence that what is " practicable " is being done. Thus, though reactionary, it is not as reactionary as the others. It is to be hoped that it will fall with the Parliament. The only reason for the Bill being made ineffective with smoke not black, that I can think of, is that this brown or yellow smoke comes from ironworks, which are apparently to be protected at every corner.

We did our best to obtain at this Conference an up-to-date statement from the Potteries ; but my letters did not even receive an answer. This is regrettable ; but the situation there is that there is a continuous extension of the use of gas firing, somewhat cautiously and experimentally, and that most potters are not yet convinced that it is of universal application. They refer to difficulties with Staffordshire blue bricks and with bone china. But Mr. Marlow, of Messrs. Minton, Hollins & Co., claimed four years ago that he could and did make then every kind of pottery in a tunnel continuous gas furnace. The furnaces which have to be heated up and cooled every time are plainly extravagant, and must for economy's sake give place to a continuous furnace, which the ware passes slowly through from one end to the other, and which is never cooled. I do not know whether the Stoke Corporation yet supplies Mond or producer gas on a large scale. It would be a great help. The manufacturers there maintain a Research Institute, and the whole situation is not without hope. But a reasonable Government stimulus to research and to progress would be a great benefit and no hardship to anyone.

Up to 1921, at any rate, smoke prosecutions were unheard of in the Potteries ; probably they are still.

From Sheffield also we made several attempts to obtain a paper giving in a careful and reasonable way the Sheffield situation ; we asked an expert to state their case, and any improvements we may hope for, but, ultimately they declined to discuss it with us. I am sorry for this, for in our controversies with their spokesman in the past we have not been much illuminated. Heat rather than light was the form of energy evolved. (Reheating is one of the industries of Sheffield.)

They say that in the rolling, puddling and reheating furnaces, particularly in the manufacture of high carbon steel, a smoky flame in the furnace itself is necessary to prevent the oxidising of the metal ; that is, very heavy smoke has to be emitted for about 12 hours, followed by rather less for another twelve ; and some afterwards. Clearly this is a case which demands treatment separately from that of the rest of the country, which merely sends its smoke shamefacedly up the chimney. As knowledge and opinion stand at present, I believe they would get from an expert Commission, such as we propose, their high steel exemption for a time. I cannot imagine any Government body which would at present seriously interfere with them. But they make, I am told by a local observer, about seven times as much smoke as they need, under cover of this exemption. If we could get rid of this, Sheffield would be a different place to live in.

Moreover, slack manufacturers, or men who will not disturb their routine, or invest capital to avoid public damage, will have to meet in such an enquiry the criticisms one hears. Furnaces have been in use at two places near Glasgow, at one in Manchester, and one in Germany, for which it is claimed that they have or had the required reducing atmosphere without smoke. And the question of a smoky gas flame is constantly brought up. These are highly technical matters on which I claim no personal authority; but it is surely desirable that a technical inquiry should be held, not before a bewildered magistrate, nor in a public meeting, but among those who know.

Then we may reach justice for the people as well as the manufacturers of the steel towns. The district from Sheffield along the Midland line to the north is the most horrible place in England, unfit for human habitation ; but I notice that amongst their disgusting smoke stacks the manufacturers are not ashamed to put their names on their works. They live far away themselves.

Outline of Reform.

It would be better to have a new Act rather than a series of complicated amendments to the Act of 1875 (for London, the

Act of 1891). The word " black" should be omitted. The principal clause in our Bill of 1914 is not quite satisfactory. It would be simpler and safer if it ran thus :—

> " If any person using or suffering to be used any furnace shall, in the event of smoke or ash, grit or other particles being emitted therefrom for periods longer than two minutes in the half-hour, if he is the occupier of the premises, or the fireman or other person employed by such employer, be liable, ... etc."

The provision which constitutes the making of manufacturing smoke a nuisance should be the first and principal clause in the Bill.

The penalties should be on a higher scale. Those inserted in the Government Bill of 1922 were not unsatisfactory. The fireman as well as the owner and manufacturer should be liable under the Act. A clause safeguarding the manufacturer against accidents should be inserted. The regulations in the Act should for the most part be definite rather than merely permissive.

It is important that the Act should include railway trains, steamships, traction engines and all road vehicles, and Government establishments.

It is universally agreed that the small local authorities are ineffective through local influence. They number 1800 and should be concentrated ; but there may be a difference of opinion as to how this should be done. The recent Bills have allocated it to the County Councils and the County Borough Councils ; but County Councils are already very much occupied, and have not been, and would not in the future be, elected mainly on this issue. The County Councils are rather far from the pressure of public opinion, though they are not supposed to be. On the whole, I think that progressive opinion favours an *ad hoc* authority, with delegates from each of the local councils included in it, who would also contribute to its expenses. I do not think that it is practicable to have a special election on this subject, hence this proposal for delegates. South Lancashire might be divided into about three such smoke authorities, and the medical officers of health and the sanitary inspectors should have representatives there. The delegates from local authorities need not be, and often should not be, already members of the authority.

The Board of Health should employ about six or more highly skilled scientific inspectors, whose business would be to keep local authorities up to the mark, with authority to prosecute, at local expense, if the local authority failed to do so. This would necessitate the establishment of a Smoke Committee at Whitehall, with the definite object of reform in view, and it

might circulate information, as the Meteorological Office, and to some extent, the Board of Health, do at present.

It has often been held that these inspectors should not commit themselves to advice, lest their advice should fail and the firm be fined for following it. One may admit that care is likely to be needed, and some tact. But the experience of the inspectors at Huddersfield and Sheffield, and still more widely in Salt Lake City and other places in America, would seem to weight the scales of usefulness the other way on the whole.

It is not actually possible to abolish all smoke. Therefore, a slight suspicion of smoke is the ideal usually aimed at. It need not be enough to do much harm to the atmosphere. Manchester allows two minutes in the half-hour of black smoke without prosecuting. This is for stoking up, and I think that so long as we use raw coal and hand stoking it can not always be avoided. I think that this limitation might be put into the Act. Some think that the Board of Health should set the standard. I should have no hesitation about this if the Board of Health had hitherto shown any zeal for improvement, but it has not. Ever since 1875, its predecessor, the Local Government Board, has had the right to interfere with any local authority which neglected to carry out the Act. The Act has been widely ignored, but the Local Government Board has never once intervened, and rather prides itself upon not having done so. It would, therefore, be safer to put this two minutes' limit per half-hour into the Act itself, with the proviso of appeal before mentioned.

America.

The chief American cities have taken up smoke abatement seriously. I have received a whole batch of their regulations. One of the striking differences between the slow ways of England and the real wakefulness of America is now found in the state of the air they breathe in their towns.

As a very long typewritten account, with diagrams, of the work in Salt Lake City, has been kindly sent me by the chief official, Mr. H. W. Clark, I think we shall learn most from it as a type of American effort, without giving a great many data from other cities. The agitation began in the winter of 1918-19, though there had been two previous attempts at reform which local and political influence had succeeded in stifling. The U.S. Bureau of Mines was induced to undertake the work. Congress voted 15,000 dollars a year, subject to an equal local levy. This was provided by the State and the City. Mr. Osborn Monnett, the Smoke Abatement Engineer of the City of Chicago, was retained to investigate and report. Private houses were found to contribute 27 per cent. of the smoke. There were heating plants,

smelters, railways and other industries. The industrial plants and boilers were in a shocking state, running from 45 to 65 per cent. on the Ringelmann Smoke Chart, whereas in the cities with a reformed atmosphere they are not considered satisfactory above 2 per cent. It was found that the rarefied atmosphere in Salt Lake City, 4500 feet above sea level, required 18 per cent. more area and 40 feet more height in the chimney than was needed in lower situations, to produce the draught.

A Smoke Ordinance was passed on November 1st, 1920, dealing in some detail with boiler and heating plants and how they should be operated. Any smoke denser than No. 3 on the Ringelmann Chart, lasting for over one minute, violated the law. When fires were being cleaned and new ones built six minutes were allowed.

A Smoke Abatement Department, with a staff of seven during the six winter months, was organised. The cost was ten cents per annum per head.

The inspectors teach the firemen, show them how to stoke, take the shovel themselves, sometimes spend half a day or a whole day in showing how smoke may be avoided. They help as well as warn. Work was organised by January 1st, 1921.

An observer is stationed on the twentieth floor of a building with an outside balcony all round, from which all the city is visible. He telephones to any factory making smoke, and keeps records. Much smoke is made in winter before daylight, so that they had a searchlight to begin with when things were so bad. This had a wonderful psychological effect on stokers. When they saw the light looking at them, they stopped smoke, though often too far off for the rather weak searchlight to penetrate effectively. During what remained of the winter season industrial smoke was reduced by 46 per cent., before the summer season allowed any structural alterations to be made.

It appeared that there were 160 regular violators of the law, and 150 others whose plants needed, and would respond to, reconstruction. These plants were investigated in detail and prescribed for, and the owners approached with persuasion to put them right. The Smoke Department had no compulsory powers. The response was good, and 100 plants were reconstructed or replaced that summer of 1921. The following winter those particular plants reduced their smoke by 84 per cent. Next winter the railways joined in, and actually paid their own inspectors, first one, and then two, to stop their locomotives smoking. These men were practically additions to the staff of the city.

Police court proceedings were taken in thirteen cases. They were all postponed, to give the owners time to fulfil their promises of conformity.

The following winter, 1921-22, showed manufacturing smoke reduced by 80 per cent. of its original amount in 1920. At the end of the winter some 190 plants still needed alteration, which was carried out during the summer by the same methods in 118 plants, some costing thousands of dollars to bring to the standard. These reformed plants reduced their smoke the following winter by 89·7 per cent.

This winter eleven cases were brought to the police court: two fined £5 each, the other sentences were postponed on promise of amendment as before. One promise was not kept.

The total reduction of industrial smoke since the bad days reached 90 per cent. in the winter of 1922-23.

In 1923 the owners of 136 plants, chiefly churches and boarding houses, were advised on new plants; and the need for maintenance of older improvements was dwelt on. One of the plants remedied this summer was the last of the big ones. It was a stand-by steam plant for making electricity only occasionally used, and its refitting cost more than a quarter of a million dollars.

The fourth winter saw the total reduction up to 93 per cent. With only 7 per cent. left of the smoke of 1920, a minimum must be near. Smoke lasting under a minute is not counted. Only one plant came before the courts.

What is left are the private houses. Advisers were sent round them in some districts in the beginning of 1923, so far as funds allowed, and great local improvement followed. The smoke was halved in the districts inspected. But this must now be made comprehensive, and the lesser evil will no doubt follow the greater. But the cost of inspection is more than with large industrial plants.

The Salt Lake Weather Bureau reports that the hours of dense smoky weather have gone down since 1920 by 39·3 per cent. and of light smoke 32·2 per cent. They do not discriminate between smoke and fog. These figures are not so striking as the others, because they include the effect of smoke from private houses, still to be tackled effectively.

The coal saved has been calculated from returns asked for. It amounts to about £6000 a year, a good return on the improvements made. Can anyone give a sound reason why Englishmen should not make their cities as fit to live in as they are in America?

Possibilities of Smoke Prevention under the Public Health Act, 1875

by R. Morton Rowe, Chief Smoke Inspector, Manchester.

The seriousness of the whole problem of smoke abatement, together with the rather surprising lack of knowledge of what can be done under the Public Health Act, 1875, to abate manufacturing smoke, is the apology offered if any is required for dealing with the rather dry subject of certain clauses of this Act.

Without for a moment pretending to legal knowledge, a fair insight into the law of the nuisance clauses has been acquired during some 28 years of dealing with smoke and other nuisances in Manchester, guided by the help given by the various gentlemen who have filled the office of prosecuting solicitor to the city of Manchester, and whose kindly aid I gratefully acknowledge.

The various phases of the question, medical, chemical, mechanical and economical, will be dealt with during the sessions of this Conference by recognised experts, each in his own sphere. The writer's claim to a hearing rests upon having for many years dealt with the manufacturing smoke problem in this city, and the not altogether enviable task of setting the law in motion against offenders who could be persuaded to tackle their own share of the question by no other means. This experience, added to many years of manufacturing on a large scale, and an invaluable year's work on the analysis of the impurities in Manchester air as assistant to the late Dr. G. H. Bailey, has produced the conviction that this question is one of the most pressing that health authorities have before them, and that, although the manufacturing smoke only meets half the problem, it is the half which can be dealt with at once, and the evil enormously reduced, if only all authorities would use the powers they have as the Manchester and some few other authorities have done and are doing. That these powers should be strengthened, and methods adopted to compel all authorities to administer the law on a common basis, goes without saying; but if the attempts at legislation which have recently been made are to become the law, we are better without them. If the Bill which has passed away with the recently deceased parliament had become law without drastic amendment, Manchester at any rate would have suffered in certain of the industrial parts of the city, as processes largely used there and now causing little nuisance would have become exempt from the law, and there being no control over them, the districts alluded to would have returned to the horrible state of smoke of twenty-five years ago.

That the other half of the problem, the domestic smoke, will be solved there is no doubt, but let it be as speedily as possible ; no effort should be wanting or expense spared to produce a smokeless fuel within the reach of the humblest householder without delay.

Some few of the more progressive communities have obtained special powers, enabling them to deal more effectively with manufacturing smoke. For example, the paltry penalty of 10s. or 20s. a day of the Public Health Act is increased to £10 in the City of Manchester, I am sure all with knowledge of the fact will admit, with beneficial results.

The sections of the Act as concerned with smoke will now be quoted under three headings :—

(*a*) Nuisance clauses.
(*b*) Administrative clauses.
(*c*) Duties and powers of local authorities, individuals and the Ministry.

NOTE.—The Local Government Board was merged in the Ministry of Health some years ago. In the clauses of the Public Health Act quoted the term Local Government Board must be replaced by the Ministry of Health.

(*a*) NUISANCE CLAUSES.

Section 91, Subsection 7, reads :—

SMOKE NUISANCE CLAUSES.

Clause (1).

" Any fireplace or furnace which does not as far as practicable consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any mill factory dyehouse brewery bakehouse or gaswork, or in any manufacturing or trade process whatsoever " ; and

Clause (2).

"Any chimney (not being the chimney of a private dwelling house) sending forth black smoke in such quantity as to be a nuisance, shall be deemed to be nuisances liable to be dealt with summarily in manner provided by this Act " :

Provided—

First (does not apply to smoke).

Secondly,

" That where a person is summoned before any Court in respect to a nuisance from a fireplace or furnace which does not consume the smoke arising from the combustible used in such fireplace or furnace, the Court shall hold

that no nuisance is created within the meaning of this Act, and dismiss the complaint if it is satisfied that such fireplace or furnace is constructed in such manner as to consume as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such fireplace or furnace has been carefully attended to by the person having the charge thereof."

Section 334 reads :—

EXEMPTION OF CERTAIN PROCESSES.

" Nothing in this Act shall be construed to extend to mines of different descriptions so as to interfere with or to obstruct the efficient working of the same; nor to the smelting of ores and minerals, nor to the calcining, puddling and rolling of iron and other metals, nor to the conversion of pig iron into wrought iron, so as to obstruct or interfere with any of such processes respectively."

These are the clauses dealing directly with smoke ; we shall come later to the clauses which provide the method of administration. The first clause of subsection 7, dealing with " any fireplace or furnace which does not as far as practicable consume the smoke," etc., is never used, as the clause itself and the proviso, owing to its wording and especially the words " as far as practicable," enable an " effective defence on technical lines to be set up."*

The second clause of subsection 7 may be called the sheet anchor of smoke prevention. In it we have an absolute prohibition of black smoke in such quantity as to be a nuisance unqualified in any way, the only exceptions being the processes mentioned in section 334 ; all other processes, whether boilers or stills or ovens or furnaces, are included.

An attempt was made to bring this clause under the second proviso, but the Court of Appeal decided that the proviso only applies to the first clause and that *no evidence of construction is admissible.* (Weekes *v.* King, 49 J.P. 709—53 L.T. (N.S.) 51.) An attempt was made in a Manchester case to override this decision, but it was held that the Court was bound by the decision in Weekes *v.* King (*Ex parte* Schofield 1891 2 Q.B. 428—56 J.P. 4).

It follows that we have only to prove to the satisfaction of the Court—

(1) The smoke is black,

(2) That it is in such quantity as to be a nuisance,

and, provided that Section 334 is not in question, a conviction is bound to follow.

Thus, regarding black smoke the matter is comparatively simple ; with smoke of any other colour there is no practicable remedy for the reason before stated.*

*Departmental Committee on Smoke, Final Report, Section 88.

(*b*) The Procedure for Administering these Clauses may now be dealt with :—

Section 93.—Information of Nuisance.

" Information of any nuisance under this Act in the district of any local authority may be given to such local authority by any person aggrieved thereby, or by any two inhabitant householders of such district, or by any officer of such authority, or by the relieving officer, or by any constable or officer of the police force of such district."

Section 94.—Service of Notice.

" On the receipt of any information respecting the existence of a nuisance the local authority shall, if satisfied of the existence of a nuisance, serve a notice on the person by whose act, default, or sufferance the nuisance arises or continues, or, if such person cannot be found, on the owner or occupier of the premises on which the nuisance arises, requiring him to abate the same within a time to be specified in the notice, and to execute such works and do such things as may be necessary for that purpose."

The notice served for a smoke nuisance under subsection 7, clause 2, is usually simply a notice to abate and to prohibit recurrence.

Section 95.—Information to Justice.

" If the person on whom a notice to abate a nuisance has been served makes default in complying with any of the requisitions thereof within the time specified, or if the nuisance, although abated since the service of the notice is, in the opinion of the local authority, likely to recur on the same premises, the local authority shall cause a complaint relating to such nuisance to be made before a justice, and such justice shall thereupon issue a summons requiring the person on whom the notice was served to appear before a court of summary jurisdiction."

Section 96.—Granting of Order to Abate.

" If the court is satisfied that the alleged nuisance exists, or that although abated it is likely to recur on the same premises, the court shall make an order on such persons requiring him to comply with all or any of the requisitions of the notice, or otherwise to abate the nuisance within a time specified in the order, and to do any works necessary for that purpose ; or an order prohibiting the recurrence of the nuisance and directing the execution of any works

necessary to prevent the recurrence; or an order both requiring abatement and prohibiting the recurrence of the nuisance.

"The court may by their order impose a penalty not exceeding five pounds on the person on whom the order is made, and shall also give directions as to the payment of all costs incurred up to the time of the hearing or making the order for abatement or prohibition of the nuisance."

It will be noticed that the Justices may inflict a penalty of £5 with the order. It is, however, rarely given or asked for. The order like the notice is to abate and prohibits recurrence.

For contravention of this order proceedings are taken under Section 98.

Section 98.—Penalty for not complying with order of justices.

"Any person not obeying an order to comply with the requisitions of the local authority or otherwise to abate the nuisance, shall, if he fails to satisfy the court that he has used all due diligence to carry out such order, be liable to a penalty not exceeding ten shillings per day during his default; and any person knowingly and wilfully acting contrary to an order of prohibition shall be liable to a penalty not exceeding twenty shillings per day during such contrary action; moreover, the local authority may enter the premises to which any order relates, and abate the nuisance, and do whatever may be necessary in execution of such order, and recover in a summary manner the expenses incurred by them from the person on whom the order is made."

These penalties are absurdly small; Manchester realised this many years ago and obtained powers by which they are increased to £10 per diem.

One need not enter into the machinery provided for appeals, right of entry for inspectors, etc., they having little direct bearing upon our view of the subject.

(*c*) Duties, Powers, etc.

Section 92 defines the duty of the local authority to inspect their districts for the detection of nuisances.

Section 92.—Duty of Local Authority.

"It shall be the duty of every local authority to cause to be made from time to time inspection of their district, with a view to ascertain what nuisances exist calling for abatement under the powers of this Act, and to enforce

the provisions of this Act in order to abate the same ; also to enforce the provisions of any Act in force within their district requiring fireplaces and furnaces to consume their own smoke."

If an individual is aggrieved by a nuisance, this is provided for in Section 105.

Section 105.—Complaint by Individual.

" Complaint may be made to a justice of the existence of a nuisance under this Act on any premises within the district of any local authority by any person aggrieved thereby, or by any inhabitant of such district, or by any owner of premises within such district, and thereupon the like proceedings shall be had with the like incidents and consequences as to making of orders, penalties for disobedience of orders, appeal, and otherwise, as in the case of a complaint relating to a nuisance made to a justice by the local authority" : . . . .

If the local authority fail in performance of their duty, Section 299 appears to provide for the Ministry of Health to enforce it.

Section 299.—Ministry of Health and Defaulting Authority.

" Where complaint is made to the Local Government Board . . . that a local authority has made default in enforcing any provisions of this Act which it is their duty to enforce, the Local Government Board, if satisfied, after due inquiry, that the authority has been guilty of the alleged default, shall make an order limiting a time for the performance of their duty in the matter of such complaint. If such duty is not performed by the time limited in the order, such order may be enforced by writ of mandamus, or the Local Government Board may appoint some person to perform such duty," . . . .

There is it seems some doubt as to the interpretation of this Section. To the lay mind the intention is clear enough, possibly the Ministry do not desire to have the onus of such proceedings thrust upon them.

One section remains, which deals with the formation of joint districts. We will quote :—

Section 279.—Joint Districts.

" Where, on the application of the local authorities of any urban or rural districts, or of any of such authorities, it appears to the Local Government Board that it would be for the advantage of such districts, or any of them,

or any parts thereof, or of any contributory places in any rural district or districts, to be formed into a united district for all or any of the purposes following; (that is to say,)

(3) For any other purposes of this Act;

"the Local Government Board may by provisional order form such districts or contributory places into a united district.

"All costs charges and expenses of and incidental to the formation of a united district shall, in the event of the united district being formed, be a first charge on the rates leviable in the united district in pursuance of this Act."

In order to efficiently supervise the smoke nuisance a whole-time inspection is necessary. This could not be done in a small district, but would be rendered possible if several of the smaller districts combined together; this section seems to provide the means.

This, then, is the general law regarding smoke nuisance which has been in force for nearly fifty years. How many of our local authorities are carrying out these provisions? Only a small minority, I fear. The improvement in those districts which have properly carried them out, points to how great a betterment there would be if all the other communities had fallen into line.

The chief points that come out from this review of the legal aspect are:—

1. There is a strong weapon to hand for dealing with manufacturing smoke.

   This requires strengthening and extending, and power to inflict larger and preferably cumulative penalties obtained.

2. Only few local authorities are carrying out their duties in regard to the smoke nuisance clauses.

   A scheme for uniformity of administration and practice is required, coupled with powers to compel all local authorities to adopt and carry it out.

3. Where the local authority does not act and the Ministry of Health will take no steps to enforce action, an aggrieved inhabitant can take action.

   It seems to me that here the League might step in through its members. If branches could be formed in every district they could bring such pressure to bear on the Ministry of Health, and if necessary take private action which, backed by the whole force of the League, would prove successful. Branches

of the League should also act as an educational force to build up a strong force of public opinion.

With the old Local Government Board as the power overruling health matters, little appears to have been done to deal with recalcitrant authorities, and with the merging of that body in the Ministry of Health considerable hopes were raised that more active steps would be taken to secure as large an abatement of this intolerable nuisance as possible.

The report of the Committee appointed under the presidency of Lord Newton was eagerly awaited, and received with mixed feelings. The report contains much that is admirable, but some glaring inconsistencies discount its value very much. It was followed by bills which, whilst they might have strengthened certain of the clauses of the Public Health Act, would have probably counterbalanced this by their reactionary policy in other ways.

The latest development of forming regional committees to ensure uniformity of administration and practice, is a step which can be made very useful and fruitful in the abolition of black smoke. It will depend, however, very largely on the backing given to it by the Ministry of Health.

Without a doubt, a strong and vigorous Smoke Abatement League can be of great help in this movement. Not only the local authorities but also the Ministry of Health will be greatly influenced and more likely to adopt a genuinely vigorous policy if this is done. Without this backing, the scheme will fizzle out, and the Ministry, having made an attempt to improve matters, will have an effective answer to any complaints which may be made. What is the answer of this Conference and of the League to this proposal ?

The law regarding railway and road locomotives has not been dealt with, as they hardly come under the 1875 Act. One may state, however, that railway locomotives emitting excessive smoke are dealt with under other Acts and convictions obtained.

The law regulating road locomotives is so worded that all light vehicles—steam motor wagons which often fill the streets with foul products of imperfect combustion—cannot be dealt with ; the heavy traction engine, however, is liable to a fine not exceeding £5 for emitting offensive smoke.

Mr. C. E. Stromeyer (Manchester Steam Users' Association) said that, dealing, first of all, with Mr. Graham's paper, it struck him that Mr. Graham was speaking as the President of the Smoke Abatement League, and that he was apparently speaking to the members of the Smoke Abatement League. The outside public did not seem to concern him at all. The outside

public wanted to know how to prevent smoke. Nobody in the room wished to have smoke. A good many years ago, his Association made hundreds of experiments on smoke prevention. The celebrated Wigan Coal Trials were carried out by the Association, and the experiments were undertaken for the purpose of ascertaining how coal could be burned without producing smoke. The result was that patents were brought out, and the celebrated " Split-Bridge " patent had a great vogue for many years. The " Split-Bridge " patent did not prevent smoke but simply diluted it. The result was a tremendous waste of fuel. They would probably not find a single " Split-Bridge " in use in England now because of the waste. The method of consumption of coal had been improved in many respects instead. He could not say that there was very much smoke in the Manchester district. This was doubtless due to the increased use of gas for domestic purposes. He remembered one really big fog since he first came to the district twenty-five years ago, but of late he only remembered white fogs which were, of course, not due to black smoke. He admitted that the climate was an abominable one, but that was not caused through the smoke, it was due to the moisture in the air. He thought the public ought to be told, first of all, what constituted smoke. If smoke were to be defined as being neither black nor brown, was the name smoke to include invisible smoke ? The invisible smoke, to his mind, was far more injurious than the visible smoke. Smoke or no smoke, there was emitted with nearly all waste gases a large quantity of sulphurous acid gas which is a very injurious substance. If it came in contact with a porous body like soot it became absorbed, and if it then came in contact with moisture and oxygen it became converted into sulphuric acid, and sulphuric acid was certainly not injurious at all. It was used in medicine. It was at one time prescribed as an anti-cholera drink. (Laughter.) The injurious part of the smoke which was sent into the air was not the black portion, it was the invisible sulphurous acid. He had an example of that the other day in London when he was looking at the marble plaques on the Albert Memorial. A keeper came up at the time, and he mentioned to

him that the carvings were very much worn down. The keeper showed him that the points which were covered with black showed lines which were less injured than the uncovered ones. Therefore, when people said that smoke did harm, they had to distinugish between black smoke and sulphurous acid. He believed the real trouble was not so much the blackness as the impurity of the air. Coke contained relatively more sulphur than coal, and would create a far worse atmosphere because it was necessary to burn very much more of it. Although the blackness of smoke was abolished by coking the impurities were increased. At the present time the Smoke Abatement League was speaking more directly to manufacturers. On the whole, the manufacturers were behaving very well, but they had large single chimneys and their smoke could be discovered quite easily. He knew of one case of a metallurgical works where they had a large number of small furnaces all discharging separately. The smoke inspector could not bring those works within the law, because they did not smoke quite long enough at a time and not quite black enough. But he gave the owners some very good advice from his point of view. He said, " Build one big chimney and lead all your flues into it." Then these works were within the law and he was able to fine them. (Laughter.) His (Mr. Stromeyer's) objection to the whole tendency of Mr. Rowe's paper was that he did not seem to care about smoke or not smoke ; all he wanted was to be able to inflict the law. They were suffering at present from a tendency amongst prominent or would-be prominent men to boast that they were the successful creators of laws.

Mr. E. Kilburn Scott (Representative of " Combustion "), said that the Ringelman smoke chart, mentioned by Mr. J. W. Graham as being in use in the United States, cost only a few cents, was only about the size of a postcard, and enabled anyone to be a smoke inspector.

The smoke pouring out of the factory chimneys around Manchester was appalling—such a thing would not be tolerated in Australia, Canada and the United States, etc., where our people lived, so why should it be allowed here ? In New York,

the central heating system came into vogue many years ago, partly because of the difficulty in obtaining " help " to do the dirty, arduous work of attending to fires and carrying coal in buildings (higher than ours), and also because anti-smoke regulations were strictly enforced.

We required stricter legislation against the making of smoke, and should drop the present lax methods. Engineers knew how to deal with the smoke evil, but people would not spend money in adopting new processes and methods so long as they could " get by " with the old methods.

One system of making smokeless fuel was started in this country by Thomas Parker so long as twenty years ago, but only recently had the making of such fuel received encouragement from civic authorities ; *e.g.*, at Nottingham a large factory was to be erected, and Glasgow Corporation were erecting a plant. Large cities ought to have plants to make smokeless fuel, for it was a civic duty to see that householders could obtain fuel which would burn smokelessly, just as much as to supply them with clean water and to collect house refuse.

The so-called " green or smoky flame " used in Sheffield for steel reheating furnaces, mentioned on a page of Mr. Graham's paper, was said to be responsible for about one-third of the smoke of Sheffield. The manufacturers maintained that in the process of reheating and rolling high carbon steel, they were unable to avoid making these vast quantities of smoke, but if the imposition of a heavy fine was certain every time such smoke was made, a solution would be forthcoming. Even with the present old-fashioned methods smoke could be much reduced, but, as a matter of fact, the whole question of reheating steel needed investigation by expert engineers with a view to trying improved methods. There were known ways of heating copper and other metals without making scale on the metal and without making smoke, and the manufacturers of tool steel and sheet steel, if they were willing, could find a way of doing it without the " green flame."

He had been in Pittsburg for two periods with an interval of twenty years between, and on the last occasion noticed a great improvement. The city was being cleaned up, just as New York had been already cleaned up, and it was not by magic, but by simple straightforward engineering. Electric furnaces were used to a large extent, and all rolling mills and factories, without exception, were driven by electric power.

The supply of electric power to rolling mills and electric furnaces, etc., provided an enormous load for the power stations, of which there were three, each larger than the largest in Sheffield. Colfax, where he had been, had three units of plant, each of 60,000 kw., and the ultimate capacity would be 300,000 kw. One of the financiers backing Pittsburg utilities came from this country, as did also Samuel Insull, who had done so much for the electrification, and therefore the relative smokelessness, of Chicago. Bold organising types would remain in this country if similar opportunities were afforded here as were obtainable overseas. Hitherto we had allowed too many picayune people to have a say in the power supplies of this country.

Electric furnaces were responsible for the latest advances in steel manufacture; for example, chrome steel, the steel of rustless cutlery, could only be made in electric furnaces, and such furnaces did not make smoke. For many generations, crucible steel manufacturers of Sheffield cutlery steel had said they could not make it except with coke from the old-fashioned and very wasteful "Beehive" ovens. The real reason was that only the best coal was used for making such beehive coke, and it was possible to make as good coke with a lower grade coal in regenerative coke ovens.

Fortunately the order had gone forth that coke makers were not to be allowed to waste coal by building any more beehive ovens, and eventually those working would all go out of use. The manufacturers would therefore have to use coke made economically in regenerative ovens, and they would be able to do it all right, for the quality of the coke depends on the coal and not much on the method. There were many other things

manufacturers could do if they tried, and especially if they were forced, and one was they could stop making smoke by shutting down their potty little steam plants and use electric power.

The inventors and initiators of this country were not encouraged here as they are abroad, partly because old men retained the control and slacked along in the ruts their fathers started. This was one reason why we needed stricter legislation for the abolition of smoke, for it would help clear out the "standpatters" —those, for example, who think Lancashire boilers are the "be all and end all" of engineering.

When Sir Philip Gibbs described New York he said that the railway stations looked like beautiful cathedrals, and this was no exaggeration. It was largely because steam locomotives were not allowed to come nearer than within about twenty miles of the city, and every main line train taken into and out of New York was hauled by underground electric power. Many of our railway stations were as grimy as coal staithes, and it was no wonder when one knew how inefficient and smoky even the better steam locomotives could be.

It was a long time since St. Patrick's Cathedral in Fifth Avenue was built, and the beautiful Episcopal Church nearly opposite, and yet they were almost as clean as when first erected. This was because bituminous coal may not be burned in New York. Why should not London and Manchester have somewhat similar regulations? Why not, indeed? Why let a relatively few people stifle the rest of us who had perforce to live in industrial areas?

He was in a Yorkshire manufacturing town this summer and left the bedroom window open, and every morning found the dressing table covered with tarry grits which obviously had been blown out of a near-by chimney during the night, when the smoke inspector could not see what was going on.

Engineers knew why these grits were blown out at night, and could make a pretty shrewd guess as to the chimneys from which they come, and the nuisance could be prevented by means

of special dust and grit collectors. But, of course, such apparatus costs money, and so the fouling of the atmosphere went on.

The present anti-smoke law was passed fifty years ago, and as there had been tremendous progress in engineering since then, it was high time that it was amended and a new law made which would really bring offenders to task. It was not enough to take action when the smoke had been made. Smoke inspectors should be trained engineers who knew the game from A to Z, and knew where and when to look. They must go inside the boiler houses when they liked and not wait for the smoky chimney signal.

Engineers could solve the problem if they were given the opportunity, but so many people seemed to think there were going to be magical short cuts and that the problem could be solved by merely talking about the matter.

At a Smoke Abatement meeting in London last spring, Col. Crompton, the eminent electrical engineer, was given a few minutes at the end of the meeting. Being a pioneer of electric lighting, he had probably done more to reduce the smoke nuisance in this country than any other man living. He was the only speaker on that occasion who really understood the problem from inside knowledge and had practical ideas for solving it, so they gave him a few minutes, and he told them that the final solution of the smoke and dust nuisance would be found in the universal adoption of electricity. It will.

The Lancashire Electric Power Company was now turning out well over 100 million units per annum, and 40 per cent. of the load was for motors for driving machinery in cotton mills, engineering works and miscellaneous factories. But even so, the change was only in spots ; for instance, in Burnley there was not a cotton mill electrically driven, whereas Blackburn, only a few miles away, had fourteen electrified mills.

All the mills and works and factories in Lancashire ought to be driven electrically, and when that came about, as come it must if we were to keep up with the rest of the industrial world, then many of the Lancashire boilers with their ugly smoky chim-

neys would pass away. Steam required for heating, boiling and process work in factories could be raised by modern watertube boilers, and the steam reserved economically provided by steam accumulators on the Ruths or some similar system. Gas-fired boilers on the Bonecourt plan were economical and made no smoke. Electrically-heated boilers were a possibility of the near future.

Much of the cocksure talk by people in the county of its origin about Lancashire boilers was foolishness. They implied that it was the only type which could give a steam reserve. Listen ! In Pittsburg, a certain company supplied steam to office buildings, hotels, large houses, etc., for heating, and to hotels and restaurants for cooking, and one of their boilers could give 400,000 lbs. of steam per hour, that was, over fifty times as much as a 30 × 8ft. diameter Lancashire boiler. In other words, if that company used Lancashire boilers, fifty of them would have been required in a building about fifteen times as large, and they would have to employ so many men that the public steam supply could not pay. The craze for Lancashire type boilers was a fetish, and it would be wise for the folks of the North to " forget " about them, as a previous generation forgot the old haystack boiler.

Alderman BENNETT (Warrington) wished to congratulate the Smoke Abatement League on their enterprise in organising the Exhibition and Conference. He happened to be a chartered accountant, and therefore did not claim to know anything about the technical and expert side of the question. He saw the matter as it presented itself to an average citizen who was interested in the beauty and cleanliness of his country. Therefore, he had been an advocate of smoke abatement for many years. The League appealed to him, as he supposed it appealed to any ordinarily intelligent person, on several grounds. He should like to quote the words of E. Nesbit (Mrs. Hubert Bland), which effectively expressed his own opinion in reference to our great industrial towns :—

" Squalid street, after squalid street,
  Endless rows of them, each the same,
Black dust under your weary feet,
Dust upon every face you meet,
Dust in their hearts, too—or so it seems—
  Dust in the place of dreams."

He often wondered how people living in such demoralising and depressing conditions could be happy. It really was not surprising that they became discontented. That discontent should be removed by giving them healthy and cleanly surroundings.

Then there was the question of sickness. He spoke with reserve, but, if half the things which he had read upon the subject were true, there was not any doubt that smoke was responsible for a great proportion of the ill-health which was one of the worst features in the life of the nation. Moreover, the presence of such an enormous quantity of dirt in the atmosphere led to a great deal of unnecessary washing, redecoration and the rest of it. He would mention another matter, as a sort of side-light on the subject, and he spoke of it with reverence. Many of them liked to erect marble tombs as a token of respect for those whom they had " loved and lost awhile " ; but in Warrington they were strongly dissuaded from doing so by the authorities on the ground that the smoke would gradually destroy the stone.

He had been fighting the evil, in his own way, for many years in his own town, and was at least beginning to feel a little more hopeful. In times gone by, whenever he had risen to speak on the subject, and he rose whenever he had an opportunity, the Council seemed to regard the matter as a sort of joke, and any advocate of smoke abatement was looked upon as a species of mild lunatic. Personally, he always had his own ideas as to who the lunatics really were, but, to show how things were moving, he might mention that, at their last meeting, his own Council had voted a subscription of £20 to one of the Smoke Abatement Societies. There were probably many others like

himself who hated filth and ugliness, but who really had not the expert knowledge or the scientific attainments to suggest the necessary remedies. He quite admitted that, if they could not abolish smoke, for the sake of their industries they would have to accept the evil. But he was convinced that they could have industrial success accompanied with great economy, and, at the same time, cleanse their atmosphere.

He was very much interested in the remarks of Mr. Kilburn Scott. He, too, had the pleasure of visiting America in the previous year, and he was specially struck with the cleanliness of New York, which was one of the busiest places on the face of the earth. There were no dense clouds of black smoke such as one saw in English towns. He, for one, wanted to see England first in everything, and especially in matters such as this. He did not like to think that America or Germany could beat us in any department whatever, and if New York could abolish the smoke nuisance, so could we.

Mr. T. Robinson (Sanitary Inspector, Brighouse) reminded the assembly of the titles of the papers they had had. The whole of the discussion so far seemed to have centred round the subjects set down for Wednesday evening, rather than on legislation as applied to smoke abatement. Mr. Graham referred to the practice in America, and there were two points well worth noting. He said, first of all, the smoke department had no compulsory powers, and yet they got such wonderful results in the American cities. In this country we had compulsory powers, and yet we could not get the same results.

Mr. Graham: No; compulsory powers to alter apparatus.

Mr. Robinson: The other point was with regard to the time limit. No account was taken of smoke that was emitted for less than one minute. Most of the towns in this country took into account any outburst of black smoke for periods of half minutes, so that in making comparison it resolved itself into a question of standards. He believed in Lancashire they had recently had a Conference with a view to getting more uniform

action in connection with the abatement of smoke nuisances. He would suggest that similar Conferences should be held throughout the country with a view to similar unity of action. As regards existing legislation, he thought it needed strengthening. Unfortunately, in the Smoke Abatement Bill recently submitted to Parliament they had certain provisions inserted which, to his mind, were very retrograde. They found what was known as "the best practicable means clause," which, to his mind, merely provided an outlet for the manufacturer to put forward his experts in the hearing of cases before magistrates. He thought a meeting like the present might give some lead on this suggested clause, because it would more than counterbalance all the other good points in the Bill if it was allowed to go forward. He thought, in many cases, local authorities were to blame for the smoke nuisance from electricity works chimneys. He had seen two or three cases reported recently where the Health Committee had prosecuted the Electricity Committee. He could not understand at all why, when such cases arose, the Council did not override the two Committees concerned, and give instructions to their electricity department to immediately abate the nuisance whatever the cause. Local authorities ought to set an example to private manufacturers. With regard to the enforcement of legislation, it was their primary function, as representatives of local authorities, to protect people who were unable to protect themselves. They knew that in ordinary steam-raising furnaces the nuisance could be abated; therefore, the man who acted regardlessly of the public welfare ought to be prosecuted. The unfortunate thing was that they were limited to such small fines, and also to the fact that they had sometimes benches of magistrates which were composed of men who sympathised with the offenders. The enforcement of smoke legislation ought to be taken out of the hands of many existing local authorities because of their unsuitability for enforcing such a measure.

Mr. J. C. Dawes (Ministry of Health) said the reason why repressive action had not brought about a higher state of efficiency in a larger number of districts in this country was

because local authorities had not exercised the powers they already had with respect to black smoke, and it would be useful to find out why they had not done so. How was it that in Manchester they could get good results, while other local authorities, having precisely the same powers, did practically nothing? This question ought properly to be faced. He was not in disagreement with Mr. Robinson or anyone else who suggested new legislation, but this did not alter the fact that the powers they already had had not been applied except by comparatively few local authorities. Supposing new legislation were possible, the will to enforce it would not come with the mere passing of the Bill, and it was that which appeared to be lacking. Referring to the matter of Regional Committees, the position was that the Ministry was aware of the fact that there was no uniformity of method in administering the Smoke Clauses of the Public Health Act, 1875, and some months previously the Lord Mayor of Manchester kindly consented to a Conference of all the local authorities who were included in the Manchester Town Planning Region being held in that building. The region extends, roughly, from Glossop to Darwen, and comprises over one hundred local authorities. The Conference was arranged by the Ministry to consider the general question of smoke abatement and to call attention to the desirability of uniformity of local procedure. The Conference set up a Committee to go into the matter and report what might be done throughout the part of Lancashire represented by it. This Committee, he understood, would discuss practical points such as emission or concession periods, observation methods and routine abatement work, and the Ministry were hopeful that something really useful would result from it. It had been suggested that other committees might usefully be formed in different parts of the country in order that more people might get together and discuss the problem, but it was felt advisable, in the first place, to see how the Lancashire Committee functioned. The Conference would be pleased to learn that Dr. Veitch Clark, Chairman of that meeting, was the Secretary and, personally, he thought the work of the Committee would be of general use throughout the

country, and in all probability much time would be saved for any committees subsequently formed in other areas. The work of the Committee would be watched by the Ministry with very great interest.

The President of the League, Mr. Graham, and Mr. Robinson had criticised the introduction of " a best practical means clause " into the Smoke Abatement Bill recently before Parliament. This point could, of course, be discussed at very great length, but he only wished to point out that in that Bill the clause had reference to smoke other than black smoke, and the original powers relating to black smoke were in no way altered. Mr. Graham had also referred to the excellent abatement work done in some of the American cities, and he thought he was correct in saying that such work had been done under " a best practical means clause " and, what is more, such a clause was effectively worked in Glasgow, where abatement work was carried out on very practical and successful lines.

The Chairman thought he had not made the very general statement that smoke repressive powers had reached the maximum of their efficiency. He had not been quite so bold as that. If he remembered rightly, what he definitely said was that in well-administered areas smoke repressive clauses had reached approximately their maximum of efficiency, and that they would, in the future, have to look for a large percentage of improvements from other sources, such as the proper combustion of coal, different sources of power, and so forth. He did not wish to create the impression that the present powers under the Public Health Act, 1875, or any other Act, were used throughout the length and breadth of the country as they ought to be. They were not. But, when they had powers existing in the country for close on fifty years, and they were not being used, it was high time they had others. This was what he meant when he said the repressive clauses had approximately reached their maximum of efficiency in all well-administered districts. That was all he wished to say personally, though many points had been raised which one would like to speak about.

Mr. GRAHAM said he should feel that, in leaving Manchester, one of his interests in life had gone when he was no longer able to have a little tilt with Mr. Stromeyer, who had made a speech that day to which he had replied half a dozen times in the *Manchester Guardian* and elsewhere. Mr. Stromeyer apparently felt that it was not worth while to get rid of the black part of smoke unless they could get rid also of the gases that were not visible. He said there was no smoke in Manchester, and he had only known one fog in twenty-five years. They were told by mystical religious writers that men could make their own environment, and it was very evident that Mr. Stromeyer possessed that bright and sunny temperament which enabled him to live through fog and smoke without perceiving them ; but surely all the dirt on their hands, on their doorsteps and window sills, and in their lungs, was due to soot, and they might well be thankful if they could get rid only of the visible part of smoke. With regard to the invisible part, due to the sulphur in the smoke, there did not seem to be a complete solution of the problem, because some coal contained as much as four per cent. of sulphur. In sulphate of ammonia a good deal of the sulphur was utilised by carbonisation and the quantity in the atmosphere lessened. He quite agreed that sulphurous acid had a highly deleterious effect upon stone and iron. It was to be hoped that medical opinion would be able to strengthen the Public Health Office in regard to smoke. He had experienced the antagonism of the old Local Government Board and the lethargy of the present Public Health Office very severely in the past. In 1912, twenty-eight representatives of various boroughs conferred with Mr. John Burns at the Local Government Board and tried to get something done. Mr. Burns was polite and interested, but nothing practical was done. Government should not wait until public opinion gave them a shove which they could not resist. They should do something which would give the country a serviceable and valuable piece of smoke legislation. Mr. Lloyd George said, and perhaps he ought to know, that no Government ever did anything good unless it was compelled. The Bills brought in by recent Governments were ineffective. They con-

tained the troublesome phrase "as far as practicable," which discouraged prosecutions. Even the Bill that was brought in in 1924 still contained this phrase for smoke that was not black. If it was not suitable to have this qualification in dealing with black smoke, how could it be suitable to have it with brown and yellow smoke? There was no reason why a straightforward Bill on the valuable lines laid down by the Smoke Inspectors' Association, of which Mr. Rowe was one of the authors, should not be adopted.

Mr. Rowe hoped the Conference would not take Mr. Stromeyer's chemistry seriously. He was wrong in every argument he put forward in that direction.

The Chairman moved that a very hearty vote of thanks be accorded to Mr. Graham and Mr. Rowe for their papers, which was carried unanimously by acclamation.

Second Session of the Conference

TUESDAY, NOVEMBER 4th, 1924.

CHAIRMAN: Councillor WILL MELLAND, J.P.,
Hon. Treasurer of the League.

THE CHAIRMAN, in introducing the author of the paper to the Conference, presumed that everyone who attended was an enthusiast in regard to atmospheric purification. What was necessary was to arouse enthusiasm in the public at large and dispel the terrible apathy which prevailed at present. This, of course, could only be done by the holding of conferences and by propaganda in the press. The Smoke Abatement League of Great Britain could be of very little use indeed as it was at present constituted, simply because the question was one of ways and means. They were crippled in carrying out anything very effective because they had very little income. The accounts had been presented that morning, and for the past eighteen months they had only received the total of £112. All the work done at present was entirely voluntary. There were no overhead charges of any sort: no office expenses, no rates, and no salaries. Only out of pocket expenses, such as postages, printing, and advertising were incurred. It was not possible to continue in that manner. Mr. Elliott, who had done such splendid work in organising the Conference and assisting in the Exhibition, had practically sacrificed the last two or three months with the two events. Of course that, again, could not go on. If they could only get an income of, say, £500 a year, they could really do some good. The organisation was not a local one, it was the Smoke Abatement League of Great Britain. It was their wish to set up branches of the League in all the principal centres of the country, which would involve a great deal of travelling about and a vast organisation. Their Conferences would lose a great deal of their usefulness unless they could convince the public that the League must be supported by Pounds, Shillings and Pence.

The following Paper was then read :—

Air Pollution

by Dr. J. S. Owens, Honorary Secretary to the Advisory Committee on Atmospheric Pollution, Meteorological Office, Air Ministry.

It may perhaps be thought unnecessary at a Conference such as this to refer to the importance of the subject of air pollution by smoke. The fact of such a conference being called into existence indicates the appreciation, at least by some, of the importance of the subject. It will do no harm, however, to draw attention to a few of the outstanding points which are perhaps not sufficiently fully realised : A human adult consumes roughly 30 lbs. of air per day and between 7 and 8 lbs. of food and water combined, yet we find the curious condition of affairs existing in which the utmost attention is paid to the purity of our food and water and very little to that of the air. One of the causes of this is the fact that while impurity in food and water is liable to produce obvious effects very rapidly, this is not the case with impurity in air ; nevertheless, the harm might be equally great though its connection with the cause is not so evident, and the time required to develop is longer.

Apart from the direct effect of impure air upon health, there is a serious loss of sunshine in our cities and also of ordinary daylight as distinct from direct sunshine. A city such as London, which is by no means as bad as others so far as air pollution is concerned, loses something like 50 per cent. of its sunshine in the winter owing to smoke, or, to put it differently, in the absence of smoke a city such as London would, in the winter, receive twice as much sunlight as at present. So far as the loss of daylight as distinct from direct sunlight is concerned there is no doubt an equal diminution due to smoke. In the Report of the Sanitary Committee of the City of Manchester, April, 1915, it is stated that the light received in November at Davyhulme was more than double that received at Whitworth Street, and even that the light received on the ground level as compared with that on the roof of the School of Technology showed an average loss of about 10 per cent. at the ground.

Again, we have the disfigurement of our cities by the deposit of soot, which has been referred to many times ; there is also the waste of energy involved in the production of smoke and in cleaning and repairing as well as the loss of time involved during dense smoke hazes.

Importance of Accurate Data.

People often want to know what is the good of measuring the degree of air pollution by smoke ; they say " what we want to know is how to prevent it." This is often merely an excuse for inaction on their part ; they often know quite well how to prevent smoke but will not do it. It will be of interest, therefore, to devote a few minutes to this question of measurement.

It is very important to obtain accurate data with regard to the pollution of the air by smoke. There is a profound psychological effect upon a city when it has been shown that the air which its inhabitants have to breathe and live in is abnormally dirty. This is often the first step towards producing an effort for improvement. Again, when a city has undertaken steps to keep its air pure it is advisable to have some means of measuring the degree of success attained.

Another interesting aspect of the use of such measurements is that they disclose the fact that health resorts credited with pure air sometimes suffer considerably from impurities carried to them from neighbouring cities. This is a point which has not received much consideration in the past, as it has been assumed that impurities produced in cities disappear in some mysterious way before the open country is reached.

This is not the case ; on the contrary such impurities travel for hundreds of miles, and the smoke produced in the manufacturing districts of the Midlands can be detected on the south coast of England.

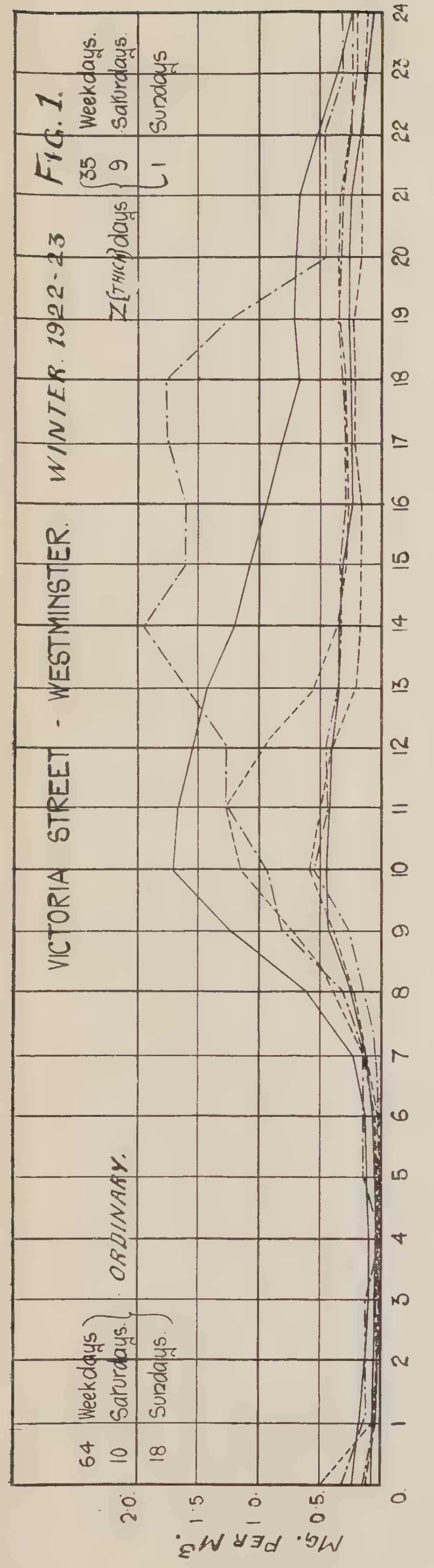
Measurement.

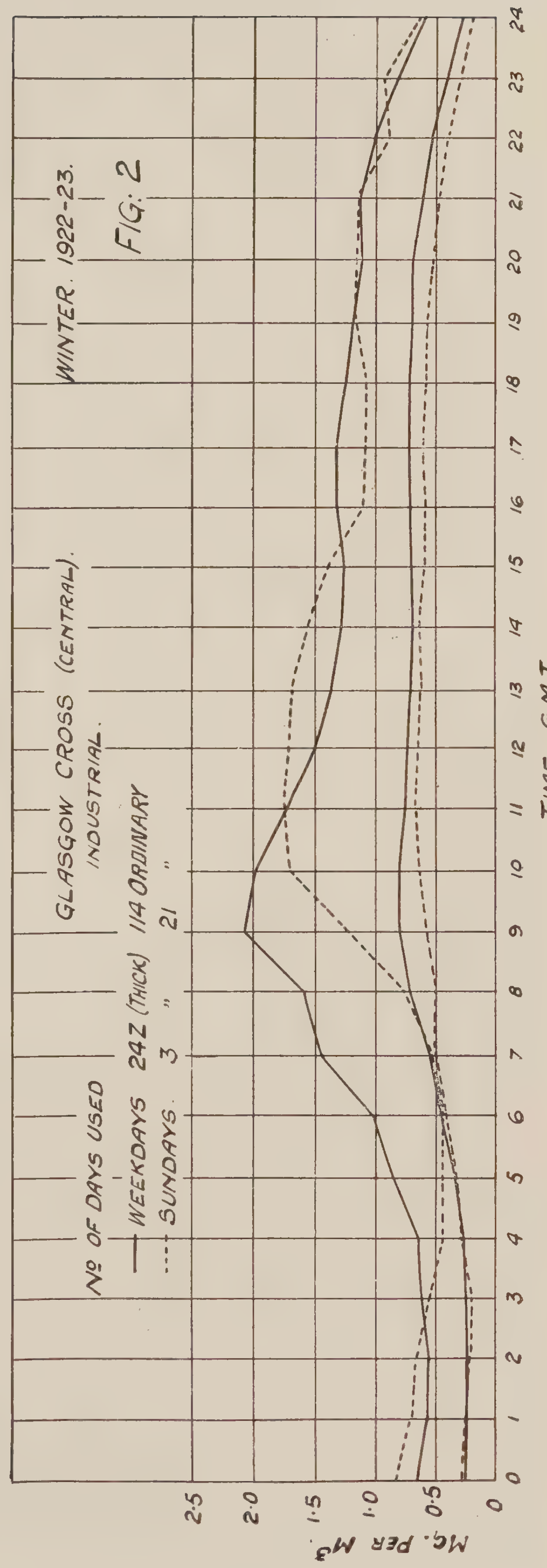
In examining the degree of pollution of the air three independent methods have been evolved and are in use by the Advisory Committee on Atmospheric Pollution. The first of these involves ascertaining the amount of deposit from the air on a given area and is very simply done by the use of an apparatus like a magnified rain gauge, several of which were used in Manchester up till 1919, and it was then possible to compare the deposit with that in other cities. For example : In 1917-18 the average monthly deposit during the whole year at the School of Technology, Manchester, was 35·87 tons per square mile. This may be compared with the Golden Lane Station in the centre of the city of London, where the mean monthly deposit was 33·15 tons per square mile during the same year. In subsequent years the deposit in London has gradually fallen until it is now about two-thirds of what it was in 1915-16. A table is given herewith showing the deposit from the air for a number of different places during the year 1923-24 :—

TOTAL DEPOSIT OF IMPURITY FROM THE AIR IN TONS PER SQUARE MILE FOR THE YEAR ENDING 31ST MARCH, 1924.

Station.	Deposit.
Rochdale	793·86
Liverpool	660·33
Blackburn	639·21
Birmingham, Central	440·35
London, Golden Lane	426·83
St. Helens	425·78
Salford	413·59
Kingston-upon-Hull	404·27
Leeds, Hunslet	393·50
Glasgow, Blythswood Square	370·12
Kingston-upon-Thames	162·46
Southport, Hesketh Park	128·10
Rothamsted	100·92

Passing from the measurement of deposit from the air, the second method adopted involves a measurement of the dust and soot particles which do not settle out of the air, or do so so slowly as to be kept in suspension by very slight movements. This measurement is based upon a filtration of the air through white filter paper and an examination of the intensity of the discoloration produced on the paper. Valuable information is obtained in this way as it gives an indication of the source of the impurity, enables a comparison of the quantity of domestic and factory smoke to be made, and indicates the distribution over the 24 hours. As an example of the sort of results obtained for distribution a curve is given for the winter of 1922-23 for London. This is reproduced from the Annual Report of the Advisory Committee on Atmospheric Pollution, and the distribution may be regarded as normal for a city of mixed residential and manufacturing type, but mainly residential or commercial. The air is comparatively clear between midnight and 6 a.m., after which a fairly rapid rise of impurity occurs, making a maximum in the forenoon about 10 o'clock, and then falling rapidly to about 5 or 6 o'clock in the afternoon, when a tendency towards a second rise is shown ; after this the fall is continued to midnight. Curves for Sundays show that the maximum in the forenoon is reached later than on weekdays by one or two hours. This is important, since it points towards the cause being purely artificial and not a natural result arising from meteorological conditions, as these would be the same on Sundays as on weekdays. A similar curve is shown for Glasgow Cross, an industrial part of the city of Glasgow, in which the delayed maximum on Sundays is very evident. In both these curves the lower set refer to days which


VICTORIA STREET - WESTMINSTER. WINTER 1922-23
FIG. 1.
ORDINARY.
64 Weekdays
10 Saturdays
18 Sundays
Z (THICK) days
35 Weekdays
9 Saturdays
1 Sundays
MG. PER M³.
TIME


GLASGOW CROSS (CENTRAL). INDUSTRIAL.
WINTER. 1922-23.
FIG: 2
Nº OF DAYS USED
WEEKDAYS 24 Z (THICK) 114 ORDINARY
SUNDAYS 3 " 21 "
MG. PER M³.
TIME. G.M.T.

have no marked smoke haze, the higher to those in which there was a very marked haze or so-called smoke fog.

Illustrating the sort of information obtained from these curves, an instrument at Tunstall, near Stoke-on-Trent, consistently showed higher impurity on Saturdays than on weekdays or Sundays, which is unusual, and was not easily understood until on enquiry it was found that the pottery ovens in the neighbourhood were usually lighted up on Friday nights or Saturday mornings. Again, at Blackburn, an instrument indicated two peaks on the curve for weekdays and Saturdays, the first between 8 and 9 a.m., and the second between 11 and 12 ; whereas on Sundays the first peak disappeared, leaving the second about the same as on weekdays and Saturdays ; thus clearly suggesting that the first peak was a result of industrial smoke, which was absent on Sundays.

The third method of examining air pollution is by counting the number of suspended dust or smoke particles, and this is comparatively easily done with suitable instruments when the necessary experience has been gained. The particles are trapped upon a microscope cover glass by means of a special instrument and examined under high magnification by means of a microscope. In this way the number of suspended dust particles per cubic centimetre or per cubic inch can be ascertained, and it is found that the number in cities such as London, Manchester and Liverpool varies from about 2000 during ordinary winter days to anything between 50,000 and 100,000 particles per cubic centimetre during thick smoke haze. All these particles are excessively small, but it does not follow that their small size makes them less harmful ; on the contrary, it may increase their harmful effect as it certainly permits them to penetrate where larger particles would fail to gain admittance. It is now a recognised fact that miners and grinders who suffer from silicosis rarely have the larger particles of silica embedded in their lungs, in fact the great majority of the particles so found are under one micron (one twenty-five thousandths of an inch) in diameter. This is mentioned merely to indicate that size of particle must not be taken as a measure of its capacity for harm.

This finely divided matter suspended in the air rises to great heights and is capable of travelling over great distances. It has been found by measurements made in the United States of America that the dust reaches up to at least 10,000 feet, but the number of particles at that level is very much less than at the ground level ; for example, the mean of observations in October and November, 1923, gave 357 particles per cubic centimetre at the ground level, steadily diminishing as the height increased to 43 at 10,000 feet.

Some curious results have been found by the use of the dust counter method, indicating the difference in the type of dust at different places. A London smoke haze, or smoke fog as it is popularly called, gave a dense black record from which on distillation tar was recovered, thus showing that tarry soot particles were present in great numbers. To get this result requires somewhat delicate manipulation as the weight of solid matter trapped by the dust counter is very small, amounting to about one four-hundredth of a milligramme in the very dense record obtained by trapping the dirt in 500 cubic centimetres of air.

Again, records taken far out at sea show a total absence of suspended dust, but near the land a haze is sometimes found composed of crystals of hygroscopic salts.

During the autumn, when the leaves have begun to fall, numbers of mould cells are found on the records, which are apparently derived from dead leaves. Again, we find scattered through the air of cities numbers of perfectly transparent glassy balls, the origin of which was for some time very obscure. These balls are so transparent and perfect that one may be used as a lens and an image obtained through it. Their size is, however, small, usually of the order of one micron or one twenty-five thousandth of an inch in diameter, so that they do not obtrude their presence upon one unless looked for very carefully under a high magnifying power.

In conclusion, the following method has occurred to me as enabling you to visualise the enormous numbers of small dust particles suspended in the air of a city like Manchester. Suppose that one of the persons now responsible for the production of smoke in Manchester were condemned to count the number of particles of such smoke which he breathes in one week in the winter. If he counts at the rate of one particle per second and works twelve hours a day without intermission, assuming his Union permits this, it would take him 54,600 years to complete the count.

Mr. Graham mentioned that Dr. Ashworth had published some very valuable figures giving the proportion of factory smoke to domestic smoke as demonstrated during the coal strike. Perhaps Dr. Ashworth would kindly state those figures for the information of the Conference.

Dr. Ashworth said that the problem of the ratio of factory to household smoke was important, but it was extremely difficult to determine. It could not be a constant quantity, but must fluctuate with the seasons, with good and bad trade, and the

distribution of houses and factories. He had made some observations of the amount of smoke during holiday times, such as New Year, Easter, Whitsuntide and the annual summer holiday in August. Altogether, he had about thirty-seven days' record of holiday times, and he could compare them with ordinary working times. He was rather doubtful, however, whether there was much definite information to be derived from the records. They could not be quite sure that in a holiday time the mills absolutely produced no smoke. The boiler fires must be kept going for the sake of keeping the mills warm. Again, it was not possible to be certain whether the houses were producing their normal amount of smoke. He had worked out his figures upon the assumption that the mills produced no smoke, and the houses went on producing smoke in the usual fashion. Under these circumstances, the factories in Rochdale gave at least 50 per cent. of the smoke emitted.

There were probably occasions, however, when the amount of factory smoke increased. He understood this result was different from the experience of other towns, for instance, Salford. A few days ago he received a very valuable pamphlet from the Medical Officer of Health of Salford, in which he showed that the comsumption of coal by factories as compared with houses was as one to two, *i.e.*, for every ton consumed in a factory two tons were consumed in a house. There were 192 factory chimneys in Salford, and there were very nearly the same number in Rochdale ; but Salford had twice the population of Rochdale. Assuming that Rochdale people consumed coal in the same way as Salford people, they might suppose that for every ton consumed in the factories one ton would be consumed in the houses. This, again, gave a ratio of 50 per cent. to 50 per cent. There were some other considerations into which he could not enter just at the moment.

Mr. Graham said that he really wanted to bring out Dr. Ashworth's figures as the result of investigations during the coal strike, giving the basis of 66 per cent. factory smoke, 23 per cent. domestic smoke, and 11 per cent. dust.

Dr. Ashworth did not know that he could add anything to those figures, but he thought that factory smoke was not less than 50 per cent. It might be as much as 66, or even more. It was an uncertain quantity, because it must vary with the state of trade, and the distribution of houses and factories in different towns.

Dr. Owens said that in London the proportion of domestic smoke to factory smoke was about two and a quarter to one. This conclusion was arrived at by comparing the Sunday smoke with that of week-days.

Mr. W. J. Smith (Gas Engineer, Bolton) wished to know if any attempt had been made to differentiate between the free carbon and what might be termed the tarry matters in the atmosphere. It seemed to him that the free carbon would be the greater sinner in cutting off the actinic rays, whereas the tarry matters would be more destructive to health in the lungs. One found that miners were peculiarly free from tubercular trouble.

Dr. Owens said that the distinction was drawn in all the analyses of the deposit obtained in the standard gauge. The tarry matter was separated from the carbonaceous matter. By "tarry matter" was understood anything that was soluble in carbon bisulphide. It did not follow, however, that the tarry matter was the injurious part of the smoke. It was very small in proportion to the carbonaceous content, and its chief effect was probably to cause the carbonaceous content to stick to whatever it fell upon. In itself, it was not very injurious. The injurious part of the smoke was the solid matter, and the sulphur which attacked building stones.

Dr. Anderson (Medical Officer of Health for Rochdale) said they in Rochdale, like Dr. Owens, wanted to get at facts and figures. Dr. Ashworth had been a pioneer and enthusiast in this work for many years, and they all appreciated the work he had done. But Rochdale rather resented the attempt in some quarters to make comparison as to which town had the cleanest or the most polluted atmosphere. Rochdale had simply faced facts.

They had placed gauges in the worst parts of the town and published the figures. But that did not justifiy the statement as made in some quarters that Rochdale was the dirtiest town in England. He was aware of towns in Lancashire which commenced to take records, but had ceased to publish results ; while some had been so modest that they had not published results at all. He maintained that, with our present knowledge, we were not in a position to make comparisons, but he hoped the work and results published for Rochdale would prove a stimulus to other towns to work for the purpose of effecting a reduction of atmospheric pollution. When comparable results were available, he was very certain that Rochdale would be found not to have the most polluted atmosphere. As Medical Officer of Health, he knew what had been done in Rochdale during the past fifteen years. A large amount of money had been spent in the increase of boiler power and installation of mechanical stoking machinery, and other possible means taken to improve atmospheric conditions.

Mr. J. C. Davies said that if it was the domestic chimney which was causing all the trouble there appeared to be no occasion to worry about a few factory chimneys. Some local authorities stated that 75 per cent. of the trouble was due to the domestic chimney, and only 25 per cent. to the factory chimney.

Dr. Owens said that there was no city which took measurements of atmospheric pollution of which he had a greater admiration than Rochdale. The public spirit of a city which continued to take observations when they admittedly came out rather high was remarkable. He had not the slightest doubt there were cities much worse than Rochdale.

A vote of thanks to the reader of the paper was carried unanimously by acclamation.

Third Session of the Conference

TUESDAY, NOVEMBER 4th, 1924

CHAIRMAN : Councillor E. D. SIMON, J.P.

THE CHAIRMAN, in introducing the readers of the papers, said it was rather a novel experience for him to attend a Smoke Abatement Conference with the organisation of which he had had nothing to do. He would like to congratulate Mr. Graham and Mr. Elliott on the excellent work they had done in getting the Conference together. The Lord Mayor of Manchester had said that morning that the opinion expressed in his (the Chairman's) book that the bulk of the smoke was due to the domestic chimneys was probably wrong. There was, however, an extraordinary confirmation of his statement in the Report published by the Medical Officer of Health for Salford. Dr. Osborne had made a very careful investigation in Salford and found that just under 6000 tons of coal were burned per week in the factories in Salford, and that, in winter, just over 11,000 tons of coal per week were burned in domestic fires. Professor Cohen had estimated that of all the coal burned in domestic fires about five per cent. went up the chimney and escaped in the form of soot. This meant that from the Salford domestic chimneys about 600 tons of soot were emitted into the atmosphere per week. As regards factory chimneys, the figure commonly taken for soot production was about one half per cent. This would mean about thirty tons per week for Salford. Upon those figures, therefore, it followed that there was twenty times as much atmospheric pollution by the domestic chimney as there was by the factory chimney.

The following papers were then read :—

The Effect of Atmospheric Impurities on Buildings

by Sir FRANK BAINES, C.V.O., C.B.E., Director of H.M. Office of Works. (Illustrated by lantern slides.)

The importance of the subject of "Smoke Abatement" can reasonably well be judged by the programme of this Conference. The dimensions of the problem and its complexity are well illustrated by the many papers to be given here, dealing with a number of separate view-points from which the subject may be approached; all of which emphasise some specialistic aspect, and all of which show the need, as well as the difficulty, of some complete synthesis. My contribution is perhaps of minor importance. I am to attempt to show the effect upon buildings of noxious vapours; the obliterating action of atmospheric impurity upon solid brick and stone; the significant destructive canker which descends upon and eats into even the everlasting granite, and debases "marble and the gilded monuments of Princes"; that renders unintelligible the writings of history, annihilating the authentic record of tradition; and finally which appears to show that modern progress and accomplishment, as if in critical disdain, carry within themselves elements of destruction and decay for their own achievement.

This may appear to be an undue indictment; but all this indeed happens when we consider the insidious and perilously speedy attack which is being delivered unremittingly, hour by hour, upon our buildings and monuments of architecture, by the noxious vapours contained in the very atmosphere we breathe.

The record of the past is largely affected; the more ancient and rare that record, the more certain appears its inevitable destruction. Our modern civilisation has bred a plague, which will pull down monuments that have withstood a thousand years of storm, some of which monuments constitute almost the only record of life and culture of their time. The seriousness of the menace and the irrevocable character of the final loss are difficult to estimate; but as we often judge a period by its recorded respect for the preservation of the facts of history, art and tradition, we should attempt to show by our action that we will neglect no steps to deserve well of the future in this particular, even if the sceptic should throw doubt on the value of the time to which we owe the duty of recorder.

The problem is of quite a respectable antiquity, as will be seen from a brief historical review I attempt to give of the winning of coal, later on in this paper.

I have under my charge numerous buildings (over 6000 in all) of every class and kind. They are situated in every part of

England, Scotland and Wales, and the Department which I have the honour to serve is responsible for the maintenance and upkeep of royal palaces, public and historic buildings, ancient monuments, museums, post offices, inland revenue buildings, customs and excise buildings, etc., etc.

I propose to show a few of these on the screen ; they have been selected as representative of those erected during

(i.) the mediæval period ; and
(ii.) the 18th Century ;

and they illustrate the magnitude and importance of the duty imposed upon the Department of maintaining and preserving them.

These have been selected as examples of a very few of the buildings of historical and architectural value which are maintained by the Office of Works. They are merely general views to show the different types with which the Department is concerned.

The amount involved in the annual maintenance and repair of these and all other official buildings is approximately £1,570,000 per annum. This figure includes a provision for heating and lighting and, of course, varies year by year.

I will give some detailed figures showing the amounts that are spent annually upon those items of maintenance which are directly connected with the impurities of the atmosphere.

On external painting between £40,000 and £50,000 per annum is spent, the repainting of the buildings being carried out every six years (pre-war, every four years).

The cost of internal painting and redecoration is about £150,000 per annum at present prices, and renewals are executed every ten years (pre-war, the period was every six years). It will thus be seen that a maximum life is demanded of the paint, and it is hardly possible that externally it will last more than six years, or internally for more than ten years.

The policy of the Department is to wash down the internal paint twice during the ten-year period, and the annual cost is about £21,000.

In addition, the internal painted surfaces are dry cleaned and dusted at frequent intervals, the cost being estimated at not less than £30,000 per annum.

Another heavy item of expenditure is the cleaning down of glazed bricks that are generally used for the construction of walls in the internal courts of buildings. No less than £15,000 per annum is incurred upon this service.

Window cleaning is not usually regarded as being an expensive item in the maintenance of a building, but it may be interesting to state that approximately £30,000 per annum is expended upon this service in London and the provinces. Windows are cleaned four times a year in the provinces and eight times a year in London and the large industrial towns, but even these periods are not sufficient to keep the windows in a reasonable state of cleanliness, and complaints constantly arise. Proposals are now being considered to alter the periods to two months and one month, respectively, and if these are adopted there will be involved an additional expenditure of £15,000 per annum.

Repairs to brick and stone and the repointing of wall surfaces are constantly taking place, and the annual cost, including the works executed upon ancient monuments and historic buildings, is approximately £100,000 per annum.

I have endeavoured to form an estimate to ascertain what proportion of these charges can be regarded as due to the impurities in the atmosphere ; it is a difficult question, but if the air were as clear and pure in towns as it is in the rural districts, I estimate that at the very least £120,000 per annum could be saved upon the maintenance of official buildings in the charge of my Department. This computation cannot, of course, be regarded as an exact figure, it can only be an approximation ; but, after taking carefully into account all the conditions and the appraisement of the serious depreciation of the buildings over the whole area of maintenance and repair work, the saving in annual charges might well be found to be from 30 to 40 per cent. of present day costs.

The domestic aspect of the problem has not been mentioned, but is of equal importance.

It is well known that the general furnishings and equipment of buildings deteriorate very rapidly in large cities, and the experience of the officers of the Department who have been stationed abroad, say at Constantinople, is that household expenditure upon cleaning and washing is very much more heavy in the smoke-laden atmosphere of London.

These general facts have been given in order to show the magnitude and importance of the maintenance of official buildings, but it will be realised that the responsibilities of one public Department are small comparatively, when the total expenditure of all other public authorities and private owners in the country is taken into account.

The building industry is one of the most important in the country, and a very large percentage of operatives are constantly

engaged upon works of redecoration, maintenance and repair. It therefore becomes a matter for very serious consideration as to how far the annual charges due to those services could be reduced, if some methods were evolved whereby the impurities due to coal smoke in the atmosphere could be eliminated and as a consequence the life of buildings prolonged.

Another and very important aspect of this problem is the loss in æsthetic value, when external surfaces of buildings become covered with grime and encrusted with soot. All buildings are not of equal architectural merit ; they increase in value as adequate and successful consideration is given to beauty of proproportion and of form, etc. At one end of the scale there is the cottage, which may possess merit of proportion and in some cases beauty of design. As an instance I mention the half-timbered cottages, scattered about England, of 15th and 16th century date, in which the art of proportion is not only excellently exercised, but the just use of the material itself has given charm, simple dignity and interest to the structure. At the other end of the scale we may mention splendid and magnificent creations such as Westminster Abbey, the Tower of London, Somerset House, St. Paul's Cathedral, etc., in which nearly every line and moulding has distinct value and has been the subject of careful thought by its creator. Buildings such as these are complete works of art and are perhaps of more importance historically than even the greatest work of contemporary painting or sculpture.

The greasy, sooty impurities in the atmosphere destroy the natural colour of stones or bricks, while the acid impurities cause decay and erosion of surfaces and mouldings, and all carved and distinctive detail.

Manchester, as well as London, affords a striking example of the obliterating grime and obscurity resulting from excessive atmospheric impurity. The majority of the buildings are constructed of sandstones, and the sooty deposit becomes absorbed into the surfaces, when the natural quality and colour of the material will never reappear. The colour of stones used is lost almost immediately under the influence of excessive atmospheric impurity. All buildings, however variable, become dull, dead black in hue, and the vital detail of relief is lost in the all-pervading envelope of soot and the detritus of decay.

Internally, buildings, particularly of the 18th century, not infrequently possess important paintings, carvings and distinctive examples of plaster, colour, iron, bronze and gilt metal work. As instances the very beautiful painted ceilings of Verrio and Thornhill at Hampton Court Palace and Greenwich Hospital can be mentioned, and the Rubens ceiling in the Banqueting House, Whitehall ; all these are seriously affected.

At Hampton Court the state rooms of Sir Christopher Wren's period are panelled in oak and contain carvings of Grinling Gibbons and his successors. Paintings, panelling and carving are very adversely affected by the atmosphere of modern London ; they become discoloured and dessicated, and much of the original beauty is irretrievably lost.

The Chapter House at Westminster Abbey contains some highly interesting and significant early wall paintings of the English primitives, dating from the 13th and 14th centuries. Their surfaces have become encrusted and blackened through exposure to the London atmosphere, and although the colours would appear still to exist beneath a black deposit, the present condition shows an astonishing example of soot accumulation through exposure to modern impure air.

For the benefit of future knowledge and record, examples of such works and buildings mentioned, with their detail, carving and ornament, demand preservation in their entirety, both externally and internally, but the problem is one of almost insuperable difficulty under present conditions.

Before I deal with the actual illustrations and examples of decay, I wish to review quite briefly the history of the production of coal. This unquestionably has had a marked effect upon the durability of buildings, particularly those of stone, in England. If an examination be made of some of the buildings erected within the last thirty or forty years, more particularly those constructed of limestone, it becomes clear that the rate of decay which is taking place is far more rapid than that which has taken place in previous centuries upon buildings of a similar character.

I propose to show upon the screen a view of the base of some pilasters forming part of the towers of the buildings in Whitehall occupied by the Ministry of Health and the Office of Works. These buildings were erected in 1912. The stone has been exposed for approximately 14 years only, and it will be observed that decay has been so rapid that the softer portions have been worn away to a depth of at least one-sixteenth of an inch. The small block of Portland stone in the same view was placed in position to show the smooth rubbed surface that was given to the pilasters when they were finished. Now, if a rate of decay so rapid as this had taken place upon all buildings in London constructed of Portland stone since the beginning of the 17th century (when Portland stone came into common use), it is obvious that there would have been very little, if any, of the original detail left for our enjoyment.

It is clear that the rate of decay within recent years has become progressively much more rapid, and, as I shall show later,

it is undoubtedly due to the increasing impurity of the London atmosphere. It becomes a matter of deep interest, therefore, to review the history of the use of coal, in the attempt to construct, as it were, a scale of progressive destruction.

It is not until towards the end of the 12th century that mineral coal is found to have entered into the records as a commodity of trade, in clear and unmistakable terms. The term (coal) was originally applied to charcoal, and mineral coal was at first and for long afterwards alluded to as sea-coal.

It appears to have first come into use when notice was taken of carboniferous strata out-cropping upon the seashore of Northumberland and the Firth of Forth.

Among the grants made to the monks of Holyrood Abbey, and confirmed by King William the Lion, who died in 1214, is one connoting the tithe of the Colliery of Carriden, near Blackness. This grant is supposed to have been made before the end of the 12th century.

Between 1210 and 1214 the Monks of Newbottle Abbey received the grant of a colliery and quarry on the seashore at Preston, a district from its earliest period famous for its production of coal.

Soon after the Magna Charta evidence accumulates of the working and carrying of coal to London. In 1228 a lane by the Fleet River in the suburbs known as "Sacoles Lane" was the mart at which coal was sold straight from the boats. It was also known as "Limeburners' Lane," and this trade was one of the earliest uses to which "sea coal" was put.

In 1238 the Monks of Newminster Abbey, near Morpeth, received a grant of land on the seashore near Blyth, to get seeward for tillage, and sea coal wherever found. A later grant in 1240 stated that the coal was conceded for the forge at one of their granges.

From this time forward references to the working and use of coal are sufficiently numerous. To Newcastle in particular the trade brought considerable benefit.

In 1268-69 a number of persons were brought before the justices to answer the Prior of Tynemouth wherefore they had come to his Mills at Shields and, amongst other charges, seized and taken away a ship laden with sea coal.

Once started, the opening of collieries soon became general, and by 1307 coal was dug, doubtless in small quantities, in all the known coalfields of England, Wales and Scotland.

At first coal was employed only by humble artisans in their trades as limeburners, smiths, etc., spreading to other classes of artificers using furnaces. It was regarded with aversion by the general public on account of its disagreeable smoke, which was even then considered detrimental to health.

From the annals of Dunstable it is learned that in 1257 Queen Eleanor was unable to stay in Nottingham on account of the smoke of sea coals. Another story of the same period relates that Edward I. interdicted the use of coal in London while his Queen (Eleanor) lay in childbed in the Tower.

Towards the end of Edward I.'s reign great efforts were made to check the spread of its use in London, on the plea that it was an innovation on established custom and an intolerable nuisance. It appears that a great increase in quantity began to be used about this time, brewers, dyers and others needing much fuel using it largely in place of wood.

The change told injuriously on the atmosphere of London, and nobles and prelates joined with the populace in demonstrating against the obnoxious fuel. A royal proclamation was issued, prohibiting its use by artificers in their furnaces. Of this little note was taken, until in 1307 a Commission of Oyer and Terminer was appointed with instructions " to enquire of all such as use sea coal in the city, or parts adjoining, and to punish them, for the first offence with great fines and ransoms, and upon the second offence to destroy their furnaces."

In the early 14th century the coal trade continued to thrive and grow, particularly on the Tyne and the Firth of Forth, and to a smaller extent on the estuaries of the Dee and Severn.

Purchases of coal figure in accounts of numerous castles being built in that period, Dunstanborough, Carnarvon, etc., for the use of smiths and limeburners.

Even in the vicinity of London these classes seem still to have continued to use it without hindrances. In 1316, *e.g.*, a sum of money was paid out of the Royal Exchequer to one John de Norton, Surveyor of Works, at Westminster Palace, to purchase iron, steel and sea coal to make heads for the King's lances.

As early as Edward II.'s reign coal was being exported from Tyne to France.

In 1313 it is noted that the monks of Jarrow took to using it mixed with wood, and in the first half of the 14th century it began to be partially used for domestic purposes.

As improvements began to be made in stone hearths and fireplaces, and the use of iron firegrates, or " chimneys " as they

were termed, a steady increase in demand opened out, and many new collieries in the great northern coalfield were worked.

The monks of Jarrow, owners of the royalty, let various collieries on lease from 1330 onwards.

Edward III. was the first king to interest himself in the Tyne coal trade. He issued writs for its regulation and letters of protection to owners of collieries on the south side of Tyne, allowing them to carry coal across the river to Newcastle, and, after paying the customs of the port, to take them to any part of the Kingdom or to Calais.

As in trade, so in mining, a settled form was developing by the latter half of the 14th century : coals and quarries were being superseded by regular mine works, of pit and adit, *i.e.*, vertical shafts and horizontal galleries. Leases also were drawn out with considerable detail.

In the 15th century demands steadily increased and new coal tracts were brought under contribution. Supplies were still obtained from shallow workings.

In the 16th century the coal trade entered on a period of greater activity. Demand had increased on the Continent, and exportation from Tyne and Forth became very lucrative at this period. This caused alarm owing to the growing scarcity of wood fuel at home, and an Act was passed in 1563 prohibiting exportation out of the realm, under penalty of confiscation of ships and cargo. Licences to export were purchased by certain families, who realised large fortunes from the monopoly.

Wood, long regarded as inexhaustible, was failing. The domestic use of coal was increasing. The introduction of cast iron and subsequent demand for cast iron cannon added to the urgency. Repeated Acts were passed for preservation of the woods. A note on the revenues of the Bishop of London, 1598, states that whereas His Lordship's predecessors had derived no small part of their income from the sale of timber, the present Bishop has to buy timber for repairs, and " he has to burn sea coals."

In spite of proclamations during Elizabeth's reign forbidding the use of coal in London while Parliament was sitting, in spite of the fact that the Queen " did find hersealfe greately greved and anoyed with the taste and smoke of the sea-cooles," and of much other opposition, people were all beginning to use coal instead of wood towards the end of the 16th century, and within a few years of the opening of the 17th the change from wood fuel to coal was becoming general.

Elizabeth, James I. and Charles I. all imposed export duties on coal ; and so prolific did the coal taxes become that by 1635 " the farm of sea coals " is spoken of as " the bravest farm the King has."

In 1638 the King had completed all arrangements for himself becoming the sole vendor of coal. But the outbreak of the Civil War prevented the realisation of this contemplated royal monopoly.

In 1648 Londoners petitioned Parliament to prohibit the importation of coal from Newcastle on account of the injury they were experiencing from smoke ; the petition failed. Again, in the reign of Charles II., John Evelyn pointed out the seriousness of the evil, and the following extract is of considerable interest :—

OLD KENSINGTON PALACE.

> One of the many projects of the indefatigable philanthropist, Mr. John Evelyn, of Sayes Court, Deptford, was a scheme for suppressing London smoke. Walking in the Palace at Whitehall, not long after the Restoration, in order to refresh himself with the site of his Royal Master's illustrious presence (the expression is his own) he was sorely disturbed by the presumptuous vapours which, issuing from certain tunnels or chimneys in the neighbourhood of Northumberland House and Scotland Yard, did " so invade the court, that all the rooms, galleries, and places about it were fill'd and infested with it ; and that to such a degree as men could hardly discern one another for the clowd, and none could support." Indeed, that high and mighty Princess, the King's only sister, " Madame " herself, accustomed as she had been to the purer air of Paris, was grievously offended, both in her breast and lungs, by this " prodigious annoyance," which not only sullied the glory of His Majesty's imperial seat, but endangered the health of his subjects. These circumstances set busy Mr. Evelyn a-thinking ; and presently gave rise to his learned tractate " Fumifugium, or, the Inconveniencie of the Aer and Smoak of London dissipated," which he inscribed to King Charles II., and in which he dealt summarily with the " hellish and dismal cloud of sea-coal," by recommending that all brewers, dyers, lime-burners, soap-boilers and the like inordinate consumers of such fuel, should be dismissed to a competent distance from the city ; and, moreover, as might be anticipated from the future author of " Sylva," that every available vacant space should at once be planted with sweet-smelling trees, shrubs and flowers. " Our august Charles," always a compliant monarch, highly approved these opportune suggestions, and a Bill was drafted accordingly. But there the matter rested. A century later,

when Evelyn's pamphlet was reprinted, nothing had been done ; while numerous glass-houses, foundries and potteries had added their baleful tribute to the " black catalogue."

The connection of Kensington Palace with the smoke of London must seem as remote as the legendary relations between Tenterden Steeple and Goodwin Sands. Yet the Whitehall smoke nuisance *was,* as a matter of fact, the proximate cause of the Palace at Kensington. If the state of things which incommoded Henrietta of Orleans had not been equally objectionable to the " asthmatic skeleton " who succeeded James II., William of Orange would never have bought Nottingham House from his Secretary of State. He could not draw breath in the " fulginous and filthy " atmosphere of Westminster ; he was unable to " lie in Town "; and he was only too willing, shortly after his accession to the throne of England, to give Daniel Finch, second Earl of Nottingham, the modest ransom of eighteen thousand guineas for a less murky " Retirement " in what was then the rural hamlet of Kensington.

Concurrently with the development of the use of coal, a great change began to take place in the density of the population of the British Isles. John Evelyn, in 1648, wrote his pamphlet and agitated for the abatement of coal smoke nuisance when the population of London was only about 500,000, and when the consumption of coal could not have been more than one ton per head of the population. At the same period the total population of England and Wales was estimated at $5\frac{1}{2}$ millions, of which number 4,100,000 persons were estimated to live in small villages and hamlets, and about 900,000 in large cities and towns, and the remainder in London.

A few figures upon the population and the growth of towns appear necessary in order to appreciate the change wrought by coal in primitive historic times. The greater part of Britain was covered by dense forests, and the fuel for all purposes was obtained from them. Domesday Book has mention of 9250 villages or manors, 80 towns (for the most part larger villages), 41 cities and boroughs (mainly our county towns), with 10 fortified towns of greater importance, namely, Canterbury, York, Nottingham, Oxford, Hereford, Leicester, Lincoln, Stafford, Chester and Colchester. The total population is calculated from Domesday Book to have been over 2,000,000, three-quarters of whom were occupied in agriculture and were distributed mainly over the south and east of England. At the time of the great Poll Tax, 1377, the total population is estimated to have been approximately $2\frac{1}{4}$ millions, and at this time the six most populous towns were given as :—

London,	population	between 30,000 and 40,000.
York	,,	11,000.
Bristol	,,	9,500.
Coventry	,,	7,000.
Norwich	,,	6,000.
Lincoln	,,	5,000.

There is, however, no data for the estimation of the population all through the Middle Ages, but at the end of the 17th century the figures become a little more definite, but there is no positive data until the commencement of the general Census Return in 1801.

The following computations of population in the 18th century are given in the Preface of the Census Return of 1831 :—

1700	...	...	5,134,516
1750	...	...	6,039,684
1801	...	...	9,187,176

The census total for England and Wales in 1921 was 37,885,242. Scotland is omitted from this return for the present in order that the figures may be comparative with those quoted in the 18th century. Concurrently with the growth of the population a great change in its distribution was made, and I will quote three instances :—

Middlesex in	1700	contained	2221	people	per	sq. mile.
,,	1750	,,	2283	,,		,,
,,	1881	,,	10387	,,		,,
Lancashire	1750	,,	156	,,		,,
,,	1881	,,	1813	,,		,,
Durham	1750	,,	138	,,		,,
,,	1881	,,	891	,,		,,

Other counties show similar changes, and the subject is very concisely illustrated by the two population maps published in Sir H. J. McKinder's " Britain and the British Isles," which show the density of population in 1700 and 1901 respectively. I show the map of 1700 upon the screen and it will be observed that if a straight line be drawn from the Wash to the mouth of the Severn, the population is most dense to the south-east of it. In the slide illustrating the map of later period the area of densest population, with the exception of London, is on the north-west side of the same line, with all the chief manufactures, textile, iron, steel and potteries, etc., clustered round the great coalfields of South Wales and the Midlands, Northumberland and Durham.

It is not necessary to enter into details concerning the chemical constituents of soot, etc., but it is perhaps desirable to recapitulate briefly facts which are probably generally known to my audience.

As the result of the combustion of coal the carbonaceous matter is driven off mainly as the gases carbon monoxide and dioxide, and as soot containing part of the ash ; the sulphur passing off into the atmosphere chiefly as the gas sulphur dioxide. There are thus two distinct impurities passed into the air, viz. :—

(1) Solid visible impurities, such as soot containing tar and ash ;
(2) Invisible gaseous impurities, the principal being dioxides of carbon and sulphur.

Of these two, soot can possibly be eliminated by more perfect methods of combustion, but the gaseous productions appear to be inevitable, and no matter how perfect the combustion of coal no practical means have yet been discovered of filtering them out. The composition and quantity of the soot produced varies with the kind of coal used, and the method of burning ; factory furnace soot contains more ash and less tar than that from domestic fires, which sometimes hold as much as 40 per cent. of tar. It is not possible to get absolutely definite data of the amount of soot emitted from flues, but estimates have been made by various experts ; one authority states that from boiler flues it amounts to from 0·5 per cent. to 0·75 per cent. of the coal burnt. It would appear, however, that it is from the domestic chimney that the greater part of the soot is produced, and authorities estimate that it amounts to as much as 6 per cent. of the coal consumed.

About 190 million tons of coal are used annually for all purposes in the United Kingdom, of which 35 million tons are burnt in domestic fires. Applying the above percentage we have :—

6 per cent. on 35,000,000 tons from domestic fires	2,100,000 tons of soot
0·5 per cent. on 155,000,000 tons from other fires	775,000 tons of soot
Or, a total of	2,875,000 tons.

The annual coal consumption of London is estimated to be between 17 and 20 million tons per annum, of which, say, seven million tons are used in domestic fires and the remainder in factories, etc. The result in this case would be :—

6 per cent. on 7,000,000 tons from domestic fires	420,000 tons of soot
0·5 per cent. on 10,000,000 tons from all other fires	50,000 tons of soot
Or, a total of	470,000 tons.

It must be admitted that these figures are perhaps open to criticism ; they are, however, used with reserve, and only to illustrate the magnitude of the problem. Even should further investigation show that such figures could be reduced by 25 or 50 per cent. there would still be sufficient soot deposited in the atmosphere to cause serious decay and disfigurement to buildings.

Passing to the gaseous impurities associated with coal smoke, by far the most important and mischievous are the sulphur gases. From complete computation sulphur in coal evolves as sulphur dioxide, which, being emitted from the chimney shafts and coming into contact with the moisture in the atmosphere, rapidly passes into sulphurous and sulphuric acids.

Various authorities have made observations in order to calculate the quantity of sulphuric acids formed in the atmosphere in different parts of the country. Without going into details it may be stated that these vary very considerably, but, to take one concrete instance, the total observed deposit of sulphuric acid per annum over the County of London (117 square miles) was about 8000 tons (Doctors H. O. Des Vœux and J. S. Owens, *The Lancet*, January 6th, 1912). Before commenting upon the effect of such impurities it is necessary to draw attention to the effect of fog in the atmosphere. It is known that the quantity of carbon dioxide increases very rapidly during a thick fog, and while 3·5 parts in 10,000 may be regarded as the average amount in country air, observations have determined the fact that it increases as much as three times the normal amount during a fog.

Other authorities are more qualified to speak upon the subject of the distribution of soot, but it is a very important matter when dealing with building structures. The latest observations point to the fact that the soot may rise during a steady and high pressure of atmosphere, and may be suspended without movement for a considerable length of time ; an alteration in the wind currents may cause a mass or cloud of such impurities to be gently driven at a high altitude over immense distances, and eventually be deposited at sea or in remote country districts. Certain amounts of soot so carried may settle and fall within a few miles of its origin, but there is little doubt that much suspended matter as well as gaseous impurities is spread through the atmosphere over wide areas, and is eventually deposited at areas remote from the centre of origin.

The effect upon buildings of atmospheric impurities involves two aspects :—

(1) The disfigurement of the building ; and
(2) The decay of the material.

Disfigurement may be dealt with readily within a building, as the principal defects here are dirt and discoloration, and limited decay caused to walls, painted surfaces, metals, windows, etc. Externally, the depreciation and disfigurement are most marked ; every city has its examples of buildings where the natural surfaces of stones and bricks have been spoilt and destroyed. It is neither easy nor inexpensive to clean buildings eighty feet in height. In cleaning, however, the opinion has been formed that clean water only is the best specific, and as an instance I would mention that the main entrance of the Law Courts, London, has been washed twice a year with pure water for twenty years, and the stone shows little signs of decay.

The most serious result of impurity in the atmosphere and of the attack of sulphur gases is undoubtedly the erosion and deterioration that take place on many of the materials used, particularly limestones, and slates and zinc. Materials such as sandstones, bricks, tiles, copper or lead are not affected to so great an extent. Limestones are used most extensively in the south of England, and a few observations upon their composition and the nature of decay may be of interest.

The action of sulphur acids upon all stones having lime or magnesia in their composition is very rapid and progressive.

Probably no stone will better exemplify what takes place than Portland, the stone most used and most relied upon for buildings of importance in London, and the stone which by general acceptance appears to have been considered as the best from the time of its utilisation by Inigo Jones and Sir Christopher Wren.

When derived from the best quarry beds, known as Brown Whitbed, it is a fine close-grained oolitic limestone of a warm creamy or pale brown colour. At its best, it deserves its reputation for durability, but this is subject to serious question arising from its variability of structure. This ranges from a structure of clean well-formed oolitic grains, similar to Ketton stone, and a dense shelly structure, often very hard, and showing on slight weathering a rather rough but not unpleasant surface.

Between these two extremes are many gradations with more scattered oons and fossils, with a matrix more or less of a mealy carbonate.

On the whole, that which assimilates most nearly to a purely oolitic grain, and with freedom from mealy carbonate, weathers best and has the best appearance.

In estimating the causes of decay, it is well to bear this variability of structure in mind. The seeming freakishness in the incidence of decay which may sometimes be observed may probably be explained by this.

When sulphuric acid is brought into contact with the stone, either by moisture, or in tarry sooty deposits afterwards saturated with moisture, chemical reaction is set up in which part of the calcium or magnesium carbonate changes to sulphate, with the dispersal of carbon dioxide.

The upper and more exposed parts of the stone suffer first, and the flatter and projecting surfaces more than the vertical. The lower more sheltered vertical surfaces, even in old buildings, are often noted to retain an unweathered face and brown or buff colour long after the exposed parts have been weathered a dead white, showing the sulphating of decay.

The calcium sulphate is much more soluble than the carbonate, the sulphite even more so, and the streaky effect often to be noted results from water charged with these salts running down and depositing them on otherwise unaffected surfaces.

Where it is checked in its flow at the soffits of cornices or strings or other projecting features, or at recessed parts of carvings, sheltered corners, and indeed anywhere where the water tends to hang or creep without immediately running off, the dissolved sulphate will generally be precipitated, and, with the tarry soot which also tends to collect and stick in the same sheltered position, is gradually formed the tenacious ugly black incrustations which are so common an obliteration on limestone buildings in London.

A large number of pieces of these incrustations have been chemically examined, detached from Portland, Bath, Anston, Mansfield and York stones, and from brickwork used in association with Portland stone, with some from slates, granite, iron, lead and zinc work. In every case sulphate was found as one of the constituents, while only in one or two cases was it found in sound parts of the material, or could it have been derived from any other source than the atmosphere. Incrustations are shown on many of the subjects of lantern slides.

In addition to direct destruction of the stone surface by the formation of sulphate, is to be noted the great alteration of volume due to conversion of carbonates to crystalline sulphates. Where limestone is attacked and part of the calcium carbonate is replaced by sulphate the increase of volume is from 1 to 1·7. Where magnesium carbonate is replaced by sulphate the increase is 1 to 4·2.

When, therefore, the acid-bearing water soaks into the stone and calcium or magnesium sulphate is formed, the physical condition developed may be grave enough to, and indeed does, cause exfoliation of the surface. Instances of this kind are very common, in which the presence of crystals of sulphate behind the

extruded flake, or fragment, shows a mechanical bursting away of the face, similar to, say, frost action.

The presence of flaws and cracks behind the face, face bedding of the stones, or soft pockets or layers in its structure, naturally gives greater opportunity for destruction, and quite considerable flakes or fragments are often forced off the solid stone. Parapets and balustrades often exhibit the various phenomena of this decay in proximity: pieces burst away as if sliced off as by a knife. Variations of surface erosion, according to exposure or texture of the stone, show from a very slight surface decay to a decay of considerable depth. The tendency to lamination is increased, and sometimes spots and fragments of exfoliation occur with incrustation on the sheltered corners and soffits of copings, and under surface of balusters, all in juxtaposition.

In softer, non-crystalline limestone, like Caen stone, exfoliation is serious and frequent, particularly where the surface has been hardened by some waterproofing preparation. Sooner or later the hard skin begins to exfoliate, and the powdering of the stone behind it, already well advanced, increases by compound measure. The same phenomena occur where an impenetrable cement is used to repair a decaying stone face, and very often where lugs of external ironwork are fixed in Anston stone window jambs, etc., the decay is more than usually progressive.

While it is not difficult to understand how sulphuric acid and sulphates from the atmosphere and soot attack lime and magnesium stones, the disintegration of bricks and slate is not so easy of explanation. It is indeed the case that corrosion due to sulphuric acid in the atmosphere would result in decay in brickwork, but the large amount of sulphate present in certain instances may be held to be due to absorption of soluble sulphates from liquids trickling down the porous surface of the brick.

It is often noted that where brick and Portland stone are used in conjunction, the latter being attacked by sulphuric acid, the brickwork is in a state of serious decay. This has been noted even where the material used with Portland stone was not porous brick but hard Pennant stone. Where the water from the decaying Portland passed over it, its surface was roughened and eroded with decay.

This may be caused by the dissolved sulphate penetrating the surface of the brick or stone, and thus loosening the surface grains by crystallisation and expansion. The same result might conceivably happen to slate or granite in similar circumstances, provided incipient natural decay had already slightly opened the cleavage planes of the slate, and if the granite were in a state to admit dissolved sulphate between its surface grains; the action here being mechanical, similar to that of frost. In the case of

granite the felspar particles are in course of time attacked directly by acid in the atmosphere, and the decay is the direct result of impurity.

Another serious effect of atmospheric impurity is the decay in magnesium limestones (of which the Houses of Parliament are constructed). The stone used here was obtained from a quarry at Anston, Yorkshire. It was selected after very careful consideration by a specially appointed committee, who visited the majority of stone quarries in England. The building was commenced in 1840 and was completed about 1854. It is therefore comparatively modern, but unfortunately the defects have been so serious that a large amount of money has had to be spent, not on works of preservation, but upon precautions taken to prevent danger or accident to members or to the general public. This stone shows lines of cleavage planes, caused, it is suggested, by diagonal pressure in the formation, due to movements of the earth. These cleavage planes are approximately at an angle of 60 degrees to the natural bed of the stone, and when formed they consisted of minute fissures which were subsequently cemented up by infiltration, these layers in the stone consisting of material harder than its general quality, yet after exposure to the atmosphere over a period of years minute fractures appear to take place at the cleavage planes. The sulphur acids of the London atmosphere penetrate the fractures and form magnesium sulphate from the basic magnesium carbonate, and thus burst the stone.

The formation of the sulphate is attended with a very large expansion, its ultimate bulk being about four times that of the original stone which it displaces ; and as a result the building is becoming a mutilated and disfigured structure. The decay is universal over the whole area of the Houses of Parliament, and roughly 30 tons of loose pieces of stone have been taken off by hand from various parts of the structure.

There is no need for me to dwell at length upon the decay of sandstones ; they are not so directly attacked by the acids of the atmosphere as are the limestones, except when they contain a calcite cementing material ; when this is the case the calcite is destroyed by the attack of the sulphur acids, and sulphate of lime is formed, the silica grains of the sand becoming loose and disintegrated and the stone breaking down. Mouldings as a consequence are eroded away, and very often large masses become detached through the percolation of the acid-laden moisture into the minute fissures or planes of cleavage.

Of the various other causes of decay, the chief and most continuous in action is water, whether in its slower effects, as rain, mist, aqueous vapour, or in mere condition of damp, or with more violent action in frost.

Whether by its direct action or as accessory and contributory agent to other mechanical or chemical erosives, it does in the long run more damage than all other causes of decay put together, being a vehicle for destructive elements. A chief factor in the formation of stone, it is also the chief agent in its destruction. Without its softening, solvent and carrying powers, all other causes of decay would probably cease to be fully effective, or would at least be very much slower in action.

Pure water alone can dissolve calcium carbonate, but with carbonic dioxide in solution its action is much more rapid. The action of water with sulphur dioxide is different. Emitted into a perfectly dry atmosphere, this gas would diffuse and be carried away harmlessly. Coming into contact with moisture in the air, it combines and forms sulphurous acid, which in turn oxidises into sulphuric acid ; the two acids in turn forming respectively sulphates or sulphites, or remaining as free acid, becoming more or less neutralised and sooner or later brought down in rain.

The acid-bearing rainwater soaks into every crevice and crack, and into the substance of the material, and it is a fact of experience that a condition of moisture, especially with lack of ventilation and stagnant air, is the medium predisposing to all forms of decay.

A suggestion has been made that barometric pressure has an effect in forcing acid-laden air into the pores of the stone, and that barometric changes might thus result in the " breathing " of masonry, and consequently increased surface damage. On this point no definite information can be given.

The case, however, appears analogous to the fact that the insulation resistance of electrical machinery is found to vary greatly with the atmospheric condition, showing that a good deal of permeation does indeed go on.

Of the actual effects of atmospheric acids upon stone, carbonic dioxide is by far the most universal and continuous in its action, but although the quantity diffused in the air is enormously greater than that of the sulphur acids, its effect is relatively mild and slow and the results of it more even and less destructive. Even the increment in quantity in town air is negligible compared with the sulphur acids. Dissolved in water, it attacks the carbonates of lime and magnesia in limestones and magnesian limestones, or the sandstones which have a cementing substance of similar material. It also attacks granite through the potash, soda and lime of its felspars, converting them into soluble carbonates which are washed out by rain. Even in the limestones and magnesian limestones, its action is very slow ; and on granites it is so slow as to be practically negligible.

It is comparatively simple to call attention to the evils of coal-smoke and atmospheric impurity ; but to make suggestions which might deal with the problem or even ameliorate existing conditions is vastly difficult. Anthracite stoves are smokeless and economical, but the supply of anthracite is limited, and it is mainly out of the bituminous coal deposits that the country will continue to obtain heating power in one form or another. Attention should certainly be directed first of all to the problem of domestic heating rather than to boiler and furnace heating ; it will not be sufficient merely to suggest some new and alternative method of consuming smoke, for it is in the national interest to prevent smoke altogether, and to extract and utilise the valuable constituents of raw coal.

My Department has been responsible for the design and construction of a large number of housing schemes, and the subject of domestic heating by means of steam or hot water from central stations has been carefully considered. It is found, however, that the proposition is not an economical one, and the estimated cost has always proved to be too heavy to be faced. The capital cost must take account of duplicate plant to provide against breakdown ; the heating mains and trenches, the necessary installation and metering required are very costly items. In special circumstances, such, for example, where electricity is generated by means of steam power, it may be possible to use exhaust steam for heating buildings in the vicinity ; ordinarily a vast amount of heating is necessarily wasted in power stations, at least nine-tenths of the available heat in the coal being dissipated in the condensing apparatus. The best efficiency that can be hoped for in the super-power stations of the future will certainly not exceed 25 per cent., so that three-quarters of the available heat will be wasted. If there are buildings requiring a heat service in the neighbourhood of a high-powered station, the waste heat can be utilised. An arrangement such as this is working very satisfactorily at South Kensington, where the large college buildings and museums are supplied with heat and hot water from our own electric generating station. Clearly, however, the conditions here are unusually favourable ; generating power stations are often remote from buildings which could utilise an appreciable part of their waste heat.

One great difficulty in supplying heating to small houses of an open " lay-out " from a central generating station, is the question of the tariff and the method of providing extensions as requirements increase ; no economical system by which the consumption of heating or domestic hot water in each house could be registered is available, so that a flat rate tariff only appears practicable ; the inevitable result would be that each householder

could use the facilities lavishly and wastefully ; and to compensate for this the tariff would have to be so high as to be prohibitive.

Small central heating systems for individual houses are a more likely proposition ; and with coke-fired boilers and hot water radiators, they could, it is thought, be planned and operated economically. They require, however, skilled attention for maintenance if good results are to be obtained, and obviously cannot be installed in vast areas of existing accommodation. The most successful means of providing for smoke abatement should operate to cause the least dislocation and disturbance, and any proposal of a revolutionary nature, however desirable it may be in itself, if forced suddenly upon the community may well be foredoomed to failure. Apart from the serious economic considerations, proposals to use gas or electricity universally for heating can never make much headway against mass opinion. From available statistics, the use of gas for domestic heating is increasing, but this is mainly in middle-class accommodation ; the small householder still finds its cost prohibitive. From the point of view of national economy, gas heating is sound in principle; some 21 per cent. of the heat content of coal is effective in heating if it is burned in a good ordinary grate. If it is converted to gas and coke at a gas works, and the gas burned in the same grate as before, about 16 per cent. of the heat in the original coal is effective, and a further 10 per cent. can be obtained by burning the coke, making a total of 26 per cent. With electric heating, however, only some 8 per cent. of the heat in the coal consumed in the power house is available to the user. This country is not well favoured with water power, and unless some more economical method is devised than the present one of generating electric energy, it is clearly to the gas industry that the nation must look for an economical solution to its present fuel problems. In particular, attention must be given to low temperature processes of carbonisation. Ordinary gas works coke, with its one per cent. of volatile matter, is not a convenient fuel for domestic use. If, however, raw coal is coked at about 500° to 600° C., instead of the 1000° usual in ordinary gas industry practice, the resultant fuel will contain about 10 per cent. of volatile matter and will burn readily in ordinary grates, producing practically no smoke. The state of affairs consequent upon a successful economic low temperature treatment of all our coal supplies would be almost Utopian. Not only would this do away almost completely with the smoke nuisance, but millions of gallons of valuable oil products would become available. An industrial civilisation as it develops appears to demand oil in ever-increasing quantities. Here Great Britain is seriously handicapped, since the Empire owns only $2\frac{1}{2}$ per cent. of the world's oil deposits and controls only 5 per cent. We are, therefore, dependent almost solely for our oil

supplies (a serious matter in time of war) on the produce of foreign lands. It is well recognised that effective low temperature treatment of coal will produce some 20 gallons of oil per ton, which in turn may be separated into varying grades of oil from the lightest motor spirit to the heaviest lubricant.

Many systems of production of smokeless fuel by means of low temperature carbonisation have been proposed, and my Department has examined the great majority of them, and experimented with the resultant fuel. It is, however, impossible to regard the problem as solved. Many of the processes seem doomed to commercial failure owing either to the extremely complicated and costly processes involved, the smallness of the output, or the unsuitability of the resultant fuel. For any smokeless fuel to compete seriously with coal for domestic purposes it is essential that it must be non-friable and easy to transport, clean to handle, easy to ignite and cheerful in appearance when burning.

The basic principle for commercial success at present would appear to be to market the oil, gas and other products at such rates as will enable the fuel to be sold at comparatively low prices, *i.e.*, oil should be regarded as the main object of the low temperature treatment, and the fuel looked upon as a by-product.

The solution, however, should not be long delayed, but it may be necessary for legislation to guide development and control and assist production.

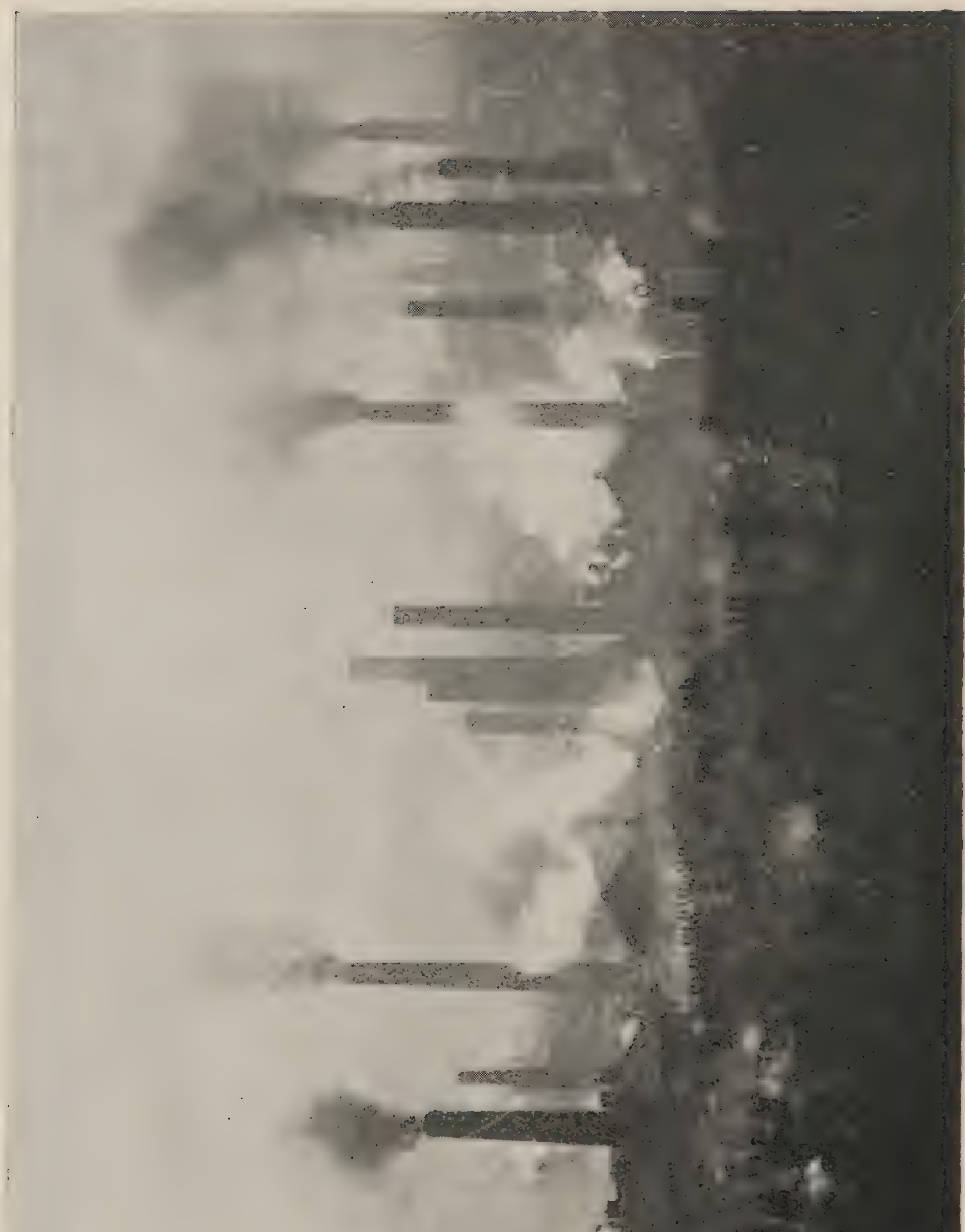
Naturally, there will be enormous opposition to any change of drastic character, as the vested interests are powerful. Once, however, smokeless fuel is a commercial proposition, it should be possible to prohibit the burning of raw coal, certainly in particular areas, which could be gradually extended until the whole country was finally embraced. The time is certainly not ripe for legislation of a wholesale character. In the north of England a great deal of domestic cooking is done with a range, which requires the lambent flame from bituminous coal. In any case, some better design of cooking range is long overdue, as the pattern at present in general use is particularly inefficient. It should not be beyond the wit of man to design a domestic range to utilise the radiant heat of a smokeless fuel, and advantage would also probably be taken of the vastly increased gas supply to extend gas cooking. Gas might even be used in connection with electric generation, and with abundant supplies of electric power the trails of smoke left by locomotives would disappear. In fact, the manifold advantages consequent upon a successful method of low temperature carbonisation are so numerous and desirable that success must be attained before very long. A wise policy of conservation of the fuel wealth at our disposal will undoubtedly result in the

production of a smokeless fuel, as well as the provision of more gas being supplied and used for domestic heating and for cooking. Large boiler plants will be fired by gas or oil, and electricity used almost exclusively for lighting and power, in which fields it has obvious and special advantages.

We must bear in mind that this country was the pioneer in industrial development ; it has ever marched as the vanguard of the nations in the exploitation of natural resources such as coal and iron. It was the prime mover in the industrial revolution, and the principal original promoter of the notable activities of modern trade and manufacture. It has, therefore, more reason to expect an early aftermath of its diligent and energetic achievements. To-day we see the nation existing as under a cloud, raised, shall we say, by its own restless, unremitting and brilliantly successful industrial exploits. In its great centres of population it lives in the gloom of its smoke and fogs, peering out upon nature, inexpressibly defiled by the results of its very virtue of unceasing industry; and perhaps regretting, in its periods of quiet thought, its forfeiture of its common birthright, clear sunlight and sweet air.

The policy of *laissez faire* was found to be untenable in the sphere of economics, witness the great advancement in factory and workshop legislation ; and it will be found to be equally untenable in this particular realm of social amelioration. The welfare of our people, the preservation of our buildings and monuments, the very structure of our social organism itself, all imperatively demand a cure of this evil, a wiping out of the debasing slur and obliteration which impure air casts upon our civilisation in the mechanical age of to-day.

When an imperative and sufficiently unified demand for a solution of a grave problem of national significance is made by the people as a whole, and when that solution would appear to be within the range of physical resolution, then it follows as inevitably as day the night that the cure will be forthcoming ; and it is the happy function of this Conference to work strenuously towards that end.



The Effect of Smoke on Vegetation

by Professor Cohen, of Leeds, with slides illustrating the damage done to plants by smoke.

The normal growth of a plant depends mainly on the free access of light, on free transpiration from a clean leaf surface and upon the nature of the soil. It can be clearly demonstrated that smoke injuriously affects vegetation in every one of these respects.

A very important—perhaps the most important—feature of the smoke problem lies in the nature of soot. Soot consists mainly of carbon, tar and ash (mineral matter), together with small quantities of sulphur, arsenic and nitrogen compounds, and frequently possesses an acid character. If it were entirely composed of carbon and mineral matter it would be rapidly removed by the first heavy rainfall, and there would be no steady accumulation of grime on brickwork, masonry and vegetation, such as strikes the eye on entering a large manufacturing town. But the tar which soot contains causes it to adhere like a varnish even to the polished surface of glass, from which a current of water will not detach it.

When one considers the very different conditions under which coal is burnt in the factory and the home, it is obvious that the character of the soot must vary. For soot is a product of incomplete combustion, and is formed partly by the mechanical removal of dust by the chimney draught and partly by the decomposition of the fuel, such as occurs in the process of destructive distillation. It might, therefore, be expected that the higher temperature and stronger draught of a factory furnace would produce a soot more by mechanical removal and less by incomplete combustion than a domestic grate, in other words, a soot containing more ash and less tar. The analyses given below illustrate these facts very clearly.

Analyses of Soot from the University, Leeds.

Constituents.	Original Coal.	Ordinary Grate Flue.	Boiler Chimney. Bottom.	Boiler Chimney. Top of Chimney 110 feet.
Carbon ...	69·30	... 40·50	... 19·24	... 27·00
Hydrogen ...	4·89	... 4·37	... 2·71	... 1·68
Tar	1·64	... 25·91	... 0·09	... 1·14
Ash	8·48	... 18·16	... 73·37	... 61·80

In connection with the subject of the proportion of tar in soot reference should be made to the table (p. 70) giving the analyses of suspended matter carried down by rain-water in different parts of Leeds. It will be seen that the proportion of tar is larger in the residential than in the industrial quarters

of the city, varying from about 4·5 per cent. at Hunslet, the centre of a large industrial area, to over 15 per cent. at Roundhay, on the outskirts of the city.

By a periodical examination of the rain-water (which carries down both soluble and insoluble impurities) derived from different localities, a fair notion of the relative quantity of these impurities has been ascertained. Ten representative stations were selected in Leeds of different types, varying from industrial to suburban, and also one at Garforth, situated about seven miles east of Leeds in an agricultural district.

The results of these experiments, which were continued for twelve months, from November, 1907, to October, 1908, are contained in the following table :—

SOLID IMPURITIES IN LEEDS' RAIN.
TONS PER SQUARE MILE PER ANNUM.

	Suspended Matter.			
Station.	Carbon.	Tar.	Ash.	Total.
INDUSTRIAL.				
1. Leeds Forge	189·6	31·4	318	539·0
2. Hunslet	241·2	19·7	187·2	448·1
3. Beeston Hill	87·1	42·6	202·5	332·2
TOWN.				
4. Philosophical Hall	99·7	22·3	120·6	242·6
RESIDENTIAL.				
5. Headingley	100·2	12·3	56·9	169·4
6. Armley	98·0	9·7	61·7	169·4
7. Woodhouse Moor	63·2	9·1	41·7	114·0
8. Kirkstall	52·3	8·0	40·3	100·6
9. Weetwood Lane	19·2	7·4	15·4	42·0
10. Roundhay	7·7	4·6	14·0	25·7

The diagram Fig. 1 represents by the length of the vertical columns the proportion of carbon, tar and ash in the soot from the rain of the various stations numbered on the horizontal line.

1. Leeds Forge
2. Hunslet
3. Beeston Hill
4. Philosophical Hall
5. Headingly
6. Armley
7. Observatory
8. Kirkstall
9. Weetwood Lane
10. Roundhay

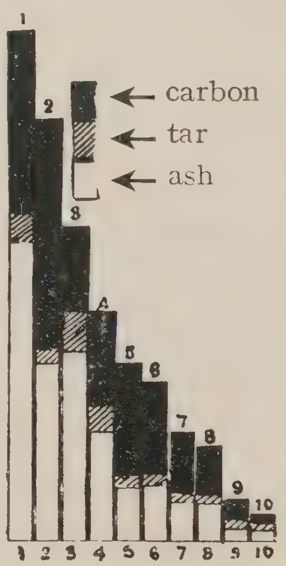


Fig. 1—Relative proportions of carbon, tar and ash.

Soot, as we have seen, is not pure carbon ; but contains varying amounts of tar. This tar adheres so tenaciously to everything that it is not even removed by rain. It is, in short, a kind of varnish. In order to ascertain the amount of this sticky material, glass plates one foot square were exposed horizontally in different parts of Leeds for three months at a time ; the loose deposit was then removed by running water and the residue analysed and weighed. The quantities deposited varied at different centres as shown in the following table :—

PERMANENT DEPOSIT OF TAR FROM SOOT.

	Station	March—June. in milligrams.	June—Sept. in milligrams.	Cwts. per sq. mile per annum.
2.	Hunslet	52·6	46·5	110
1–4.	Kirkstall Road ... (between 1 and 4)	26·2	31·1	64
4.	Philosophical Hall ...	26·4	30·4	63
5.	Headingley	11·3	17·2	27
7.	Woodhouse Moor ...	15·4	9·0	32
10.	Roundhay	1·9	2·1	4·5

It will be seen that the ratio of the deposit at Roundhay to that at Hunslet is almost exactly 1 to 24, which was the ratio obtained in the previous set of experiments for town and country, and approximates to that of the total suspended matter, namely, 1 to 17 in the two localities.

Fig. 2.

It has already been pointed out that soot may exert a detrimental effect on the growth of plants in three ways, namely, by

blocking up the stomata and thus impeding the process of transpiration; by coating the leaf and so reducing the intensity of light and at the same time affecting the assimilation of carbon dioxide, and lastly by the corrosive effect of the acid it contains. In both cases the tarry deposit plays an important part. Fig. 2 is a photograph of a holly leaf grown in the grounds of the University. From one half of the leaf the soot has been removed and the green colour then bleached, whilst the soot remained intact on the other half.

Leaves, especially evergreens, are thus coated with a black adhesive deposit which not only absorbs the light and so arrests assimilation, but has a much more serious effect in permanently blocking up the stomata. The conifers appear to be the most

Fig. 3.—Stomata of Silver Fir.

sensitive of all plants to the influence of smoke, and their characteristic sunk stomata, which serve the purpose of minimising transpiration, form very efficient traps for particles of soot. Fig. 3 is a magnified section of the leaf of a silver fir.

In addition to the blocking of the stomata, the coating of the leaves with a tarry deposit as well as the lowered intensity of light by the smoke cloud will tend to retard assimilation.

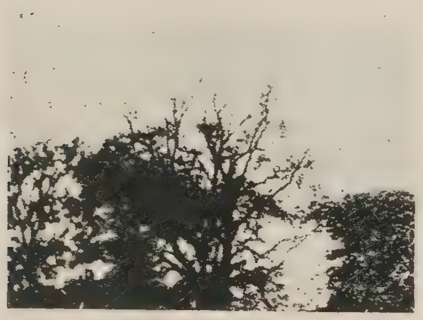
A comparison has been made of the rate of assimilation of carbon dioxide by laurel leaves from different parts of Leeds, the results of which are summarised in the following table. Taking 100 as representing the rate per unit area of a clean leaf grown on the outskirts of Leeds (Weetwood Lane), then the rate of assimilation for the other stations is given as follows :—

Station	9 ...	Weetwood Lane	100
,,	5 ...	Headingley	52·8
,,	7 ...	The University	41·8
,,	1–7 ...	Clarendon Road	15·2
,,	1–7 ...	,, (after cleaning)	24·2
,,	4 ...	City Square	11·6
,,	4 ...	,, (after cleaning) ...	19·2
,,	1–4 ...	Hanover Square	8·0

The method of carrying out the experiments was to place three leaves of the current season's growth in a flat wooden box with glass sides, and draw air through at the rate of about 18 litres per hour for 10 hours. The air, after passing over the leaves, was deprived of its carbon dioxide by means of caustic soda solution, and the amount of absorbed carbon dioxide deter-

Hunslet
Suspended Matter — 1565 lbs.
Acidity — — 19 „

University
Suspended Matter — 399 lbs.
Acidity — — 26 „



Headingley Hill
Suspended Matter — 273 lbs.
Acidity — — 185 „

Weetwood Lane
Suspended Matter — 147 lbs.
Acidity — — 11 „

Fig. 4

mined by neutralisation with standard acid. The deposition of acid along with soot is probably one of the chief causes of the early withering which is characteristic of many forms of town vegetation. Ash trees in the cleaner parts of Leeds often retain their leaves some four or even six weeks longer then those in the more polluted districts. The effect of this acid is shown in the accompanying Fig. 4 of ash trees photographed on the same day in different parts of Leeds.

The corrosive effect of the acid is further illustrated by the pitting of the leaf surface as well as the corrosion round the edge which in such cases turns a brown colour.

The presence of suspended matter in the atmosphere has a marked effect upon the amount of daylight, and it has been possible to record by means of a chemical method the amount of daylight at different centres within and outside the town.

The following table contains the records for the last few days of May and about the first half of June, 1910, from which it will be seen that on some days the industrial district of Hunslet receives less than half the daylight of the outside residential centres.

Date.	2 Hunslet.	4 Philosophical Hall.	5 Headingley.	9 Weetwood Lane.	11 Garforth
May 29	5·5	—	6·2	6·8	7·2
30	4·6	—	5·1	5·8	6·3
31	3·2	—	4·4	5·2	5·6
June 1	3·5	—	4·9	4·6	5·3
2	4·7	—	4·9	5·6	5·7
3	5·4	5·4	5·7	5·9	5·6
4	2·9	3·2	3·4	3·8	4·2
5	3·0	3·8	4·3	5·4	4·5
6	2·9	4·6	4·8	5·6	6·3
7	4·5	5·6	5·7	6·1	6·7
8	2·1	4·5	4·8	5·2	5·8
9	2·2	4·2	4·4	4·5	4·9
10	2·0	4·2	4·4	5·0	4·8
11	2·0	3·6	3·9	5·2	5·0
12	3·3	5·9	6·0	6·4	6·8
13	2·0	4·9	5·0	5·2	5·6
14	3·1	4·9	5·1	5·2	5·0
15	2·1	4·1	3·9	4·8	5·1
16	2·1	4·1	4·0	4·9	4·7

The results exhibit a striking relation between the amount of suspended matter in the air and the intensity of the light. These relations are indicated by the dark and light columns in the diagram, Fig. 5.

2. Hunslet
3. Beeston Hill
4. Philosophical Hall
5. Headingley
7. Observatory
9. Weetwood Lane

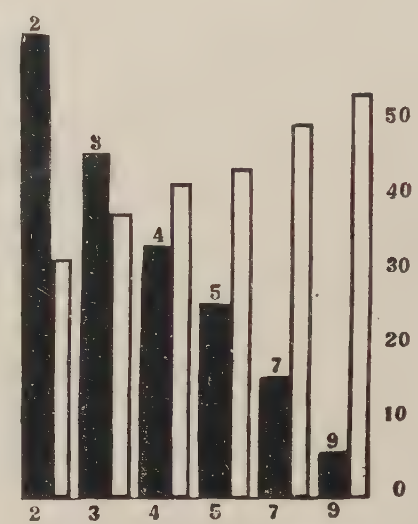


Fig. 5.

Influence of Suspended Matter on Intensity of Light.

Coal contains small quantities of sulphur, the amount of which varies from 1 to 2 per cent. On complete combustion the sulphur is evolved as sulphur dioxide, which in contact with air and moisture passes rapidly into sulphuric acid. This acid is a strongly corrosive substance. It attacks mortar, masonry, fabrics and metal-work, and is highly injurious to vegetation.

The acid carried down by rain attacks the nitrifying and other organisms in the soil essential to the growth of the plant.

Fig. 6.

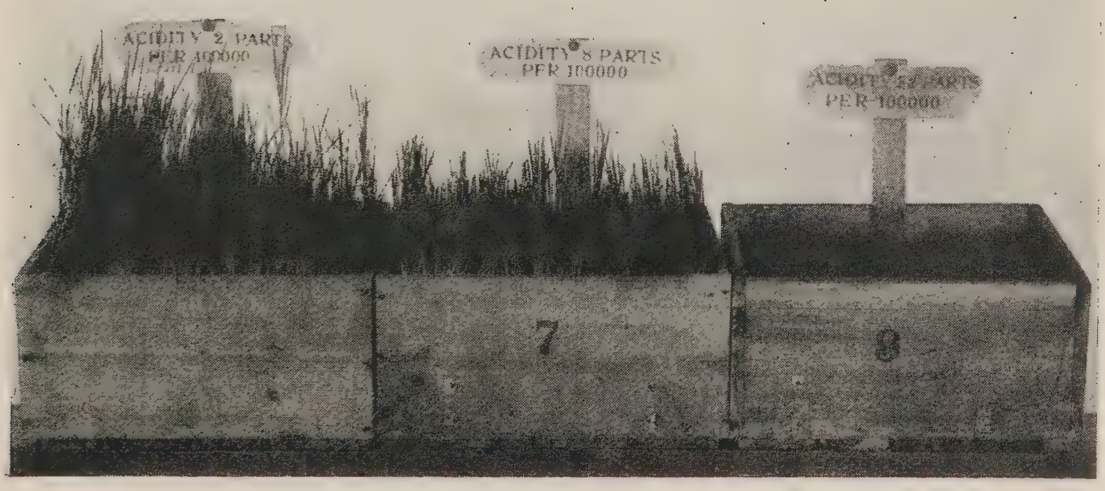


Fig. 7.

NUMBER OF BACTERIA IN SOIL WATERED WITH NEUTRAL AND ACID RAIN-WATER.

	In 1 gram of soil.
Garforth, neutralised	5,228,000
,, unneutralised	1,690,000
Leeds	1,170,000
1 part per 100,000 (sulphuric acid)	1,260,000
2 parts ,, ,, ...	1,100,000
4 ,, ,, ,, ...	690,000
8 ,, ,, ,, ...	130,000
16 ,, ,, ,, ...	40,000
32 ,, ,, ,, ...	15,000

The effect is seen in the accompanying Figs. 6 and 7, which show the marked effect of acid on the same grass seed grown in the same soil, but watered with neutral and acid water.

Fig. 8.
Lettuces grown in different parts of Leeds from the same seed.

Fig. 9.
Radishes grown in different parts of Leeds from the same seed.

Similar results have been obtained with various cereals and vegetables grown from the same seed and in the same soil, but exposed to a different atmospheric environment (see Figs. 8 and 9).

Fig. 10.

An examination of a felled tree will often give information as to the condition of the atmosphere by observing the annual

rings on the cross section of the trunk. A good example is that of a Scotch fir which, after the erection of a neighbouring shale works, gradually died and was ultimately cut down. The section is shown in Fig. 10. In consequence of the acid fumes and smoke-laden atmosphere from the works, the diameter of the annual rings became at once narrower, and it is possible by counting the narrow rings from the time the tree was cut down to fix the year when the works were erected.

There is one further aspect of the smoke question which is of no little interest to those who love flowers, namely, that the presence of coal smoke affects the colour of flowers. Generally speaking, the more polluted the atmosphere, the paler the tint. Blues run to white and bronzes to yellow. Blue Michaelmas daisies after a few years give white flowers, and red wallflowers turn yellow.

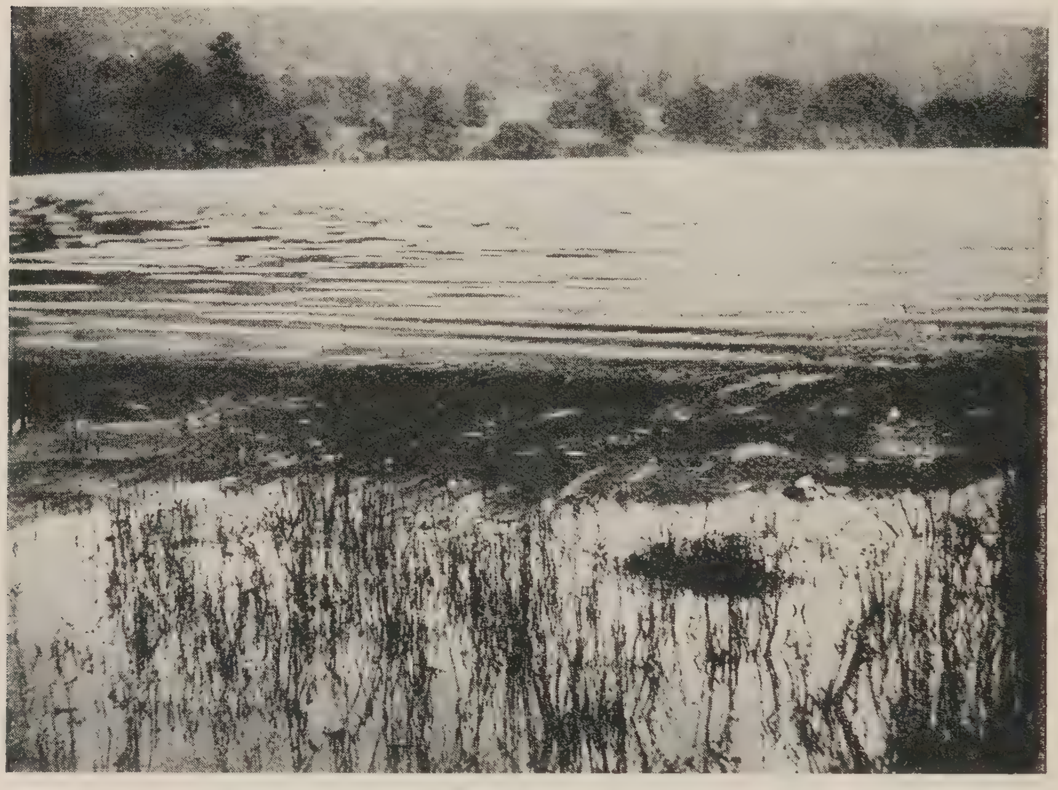


Fig. 11.
Coniston Lake, showing black fringe of soot.

The vital energy of a plant seems to be seriously affected by smoke and shows itself in its inability to survive the winter. It is, for example, unsafe to plant in the autumn, wallflowers, cabbage and spinach, where the atmosphere is laden with smoke.*

* A very full account of the action of smoke on particular groups of plants is given by Dr. A. G. Ruston, "Annals of Applied Biology," 1921, VII, 390.

How far the smoke from an industrial town will carry is difficult to estimate. That it will travel 50 miles or more is quite certain. I have found microscopic crystals of salt from the spray of the Irish Sea after a heavy south-westerly gale on glass plates placed on the outskirts of Leeds, a distance of about 60 miles. It is obvious that the lighter particles of soot will carry much farther. That such a dispersal of soot particles is probable is seen from the following fact, that on certain occasions after a steady downpour of rain the surface of Coniston Lake is seen to be covered with a greasy film of soot which, with a slight wind, accumulates at the edge of the water, forming a black sooty fringe, as seen in the accompanying photograph, Fig. 11.

Mr. W. M. Mason (Manager, British Commercial Gas Association) said that Sir Frank Baines had given them a wonderful picture of the wrong side of things. Had he a companion picture which was equally true, and which showed the solution of the problem ?

The Chairman pointed out they were dealing with the damage done to buildings and plants. The question of the solution of the problem would be dealt with at the other Sessions.

Dr. Des Vœux referred to an experiment made by Dr. Jenner, of vaccination fame. He was a Gloucestershire man, and visited London from time to time. He was very interested to ascertain how far the smoke of London spread beyond the metropolitan area. When driving out of London, every few minutes he applied his handkerchief to his nose, and when he could smell the smoke he said, " I am out of the smoke." He could not smell it in London, because his nose had got accustomed to it, but upon reaching the clear country air he could detect it. In Jenner's time the smoke reached three miles out of London ; now it was sixty.

The Chairman moved a vote of thanks to the readers of the papers, which was carried unanimously by approbation.

Fourth Session of the Conference

Wednesday, November 5th, 1924

Chairman: Alderman Sir WILLIAM KAY, J.P.
(Chairman of the Manchester Corporation Gas Committee), accompanied by
The Lord Mayor of Manchester, Ald. W. T. Jackson, J.P.

LOW TEMPERATURE CARBONISATION AND SMOKELESS FUEL.

The Chairman, in introducing the readers of the papers, said he might very briefly say, just officially, that the Gas Department welcomed this Smoke Abatement Conference probably more than any other public department of the Corporation. Their interests were entirely similar. The efficiency and economy which could be achieved by the proper distillation of coal was to them a matter of the utmost importance.

Those of them who had lived in Manchester for many years were bound to admit the great improvement in the atmospheric conditions to which the great increase in gas consumption had very largely led. He was somewhat unique in regard to Corporation service inasmuch as, in addition to being the Chairman of the Gas Committee, he served an apprenticeship of nearly eight years as Deputy-Chairman of the Electricity Committee.

He well remembered being present at a very private conference between Lord Moulton and various members of the Gas Committees, when Lord Moulton said, " Gentlemen, you must not forget that the men I have before me control the most important business in this kingdom for the winning of the war." It must not be forgotten that the gas industry, if properly handled with vision, controlled to-day, through the destructive distillation of coal, the economic future of this country.

He wanted them to look very carefully at the results of the two undertakings, gas and electricity, side by side, and the resulting product of a ton of coal in either case. In the one case they had so many thousand units of electricity plus cinders ; in the other case they had gas—whether made by low temperature carbonisation or by other methods of manufacture—with a thousand and one products, too numerous to mention. At this session they were concerned with low temperature carbonisation.

Mr. Maclaurin would no doubt tell them something about low temperature carbonisation. All that he himself was concerned with, as Chairman of the Gas Committee of the Corporation, was this, that if the promoters of low temperature carbonisation would come along with a scheme, an economic scheme, which showed more profit than he was making to-day, he could promise them that the gas industry would give it a very hearty welcome. At any rate he could say that for the Manchester Corporation. But he thought the ratepayers would expect him to be perfectly convinced that the one scheme was better than the other before he swapped horses in the middle of the stream. The future of the gas industry was a great one.

Under those circumstances he was very happy indeed, as the Chairman of the Gas Committee, in the presence of the Lord Mayor, to welcome the members of the Conference. Some of them had had the opportunity of seeing the municipality's latest venture at Bradford Road that morning. They had come to the Manchester Town Hall to discuss this problem of smoke abatement, which should be treated as a national problem ; and all were welcome.

The following papers were then read :—

A Description of the Smokeless Fuel Plant for Glasgow

by Mr. Robert Maclaurin.

I have been asked to describe to you the Maclaurin Patent Smokeless Fuel Plant at present being erected for the Cor-

poration of Glasgow, and I will endeavour to present its main features as briefly as possible.

The plant is being erected in the Dalmarnock Gas Works by Messrs. Blair, Campbell & McLean, Ltd., of Govan, the general lay-out having been worked out by them in consultation with Mr. McLusky, General Manager of the Gas Department, Mr. Harrison, Chief Engineering Assistant, and Mr. Frazer, Manager of Dalmarnock Gas Works.

The result is the evolution of what I consider will be a very compact and satisfactory installation.

Naturally a description should begin with the arrival of the coal. The coal will be drawn from the coalfields adjacent to Glasgow, from which plenty of suitable coals are obtainable. The type of coal preferred will be of the low coking variety, that is, those coals whose coking powers are too low for making good coke in coke ovens, and which have a small percentage of ash. The volatile matter can be from 25 to 40 per cent. The coal delivered may vary from large screened to washed treble nuts and it will be delivered by rail alongside the plant. The waggons will be emptied by a rotary waggon tippler on to a grid, where any very large pieces will be broken by hand. From this the coal passes to the boot of an elevator, and by this it is conveyed to the coal bunkers above the plant. These bunkers will hold 200 tons of coal and therefore there will be no necessity for taking in coal on Sundays.

From the coal bunkers the coal is delivered to measuring hoppers holding about one ton each. From these the coal is dropped into the plant by lowering the usual type of producer bell (see fig. 1).

I will now describe the plant into which the coal is put.

The Glasgow installation consists of a battery of 5 units, each unit being capable of carbonising 20 tons of coal per day of 24 hours.

The general appearance of the producer unit (see fig. 1) is somewhat like that of a blast furnace, but it is built square and raised from the ground on piers. The height from charging hoppers to discharging chutes is 36 feet, and the internal width at the widest point is 8 feet, tapering upwards and downwards.

Where the air enters a centre wall divides the plant into two equal sized chambers. The air enters through ports in the centre wall and also in the side walls opposite. The coke after cooling is discharged through chutes at the bottom.

In starting up for the first time the producer is filled up to a little above the air ports with ashes. At this point there are doors which can be used for lighting or for inspection if any trouble should arise. Through these doors a quantity of wood is inserted and lighted. When properly ignited, the producer is rapidly

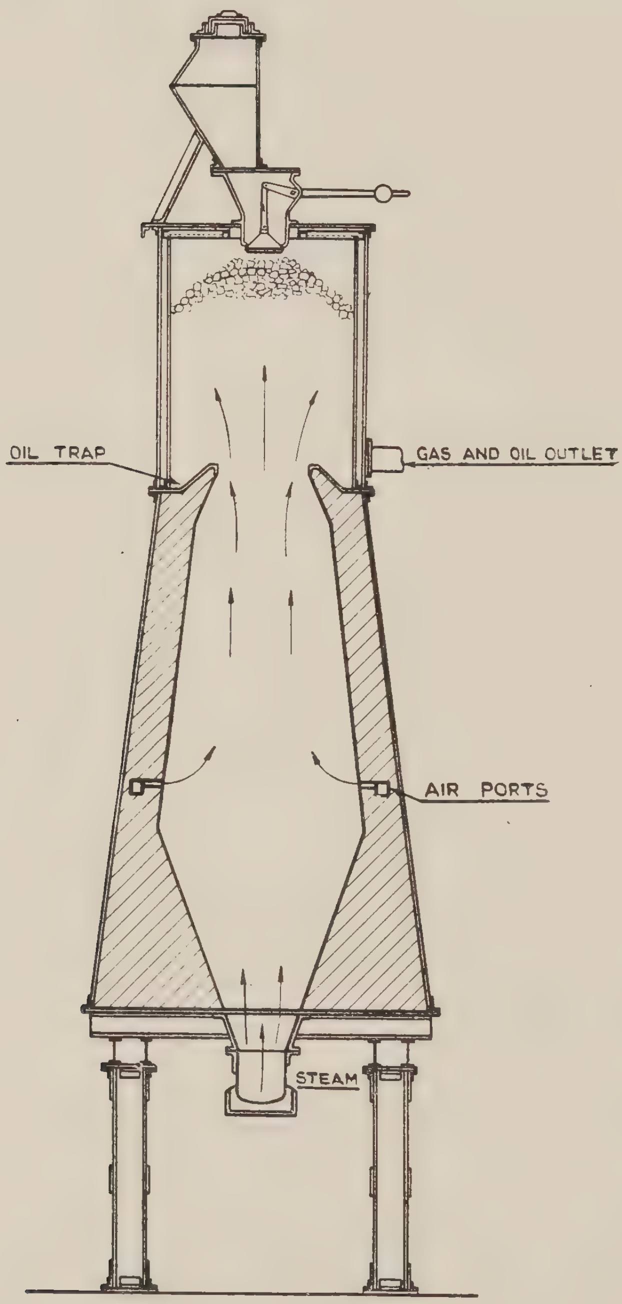


Fig. 1

filled to the top with coke ; the air blast being kept going all the time. When the heat has travelled well up the producer, sufficient ash is discharged to permit a ton of coal being dropped in through the bell. Every hour thereafter a discharge is made and approximately one ton of coal admitted. After 20 hours

the first charge of coal will be approaching the combustion zone, and at from 25 to 30 hours the first coke made from the coal added will be withdrawn.

It has, therefore, taken 20 hours to raise the coal from 15° C. to the desired coking temperature, which is about 700° C. higher. The coal drops about one foot, and rises in temperature about 35° C. per hour. This very gradual increase in temperature modifies the nature of the coke, so that the product is quite different from the usual gas work product.

The coke is sometimes so little changed from the original coal that it is difficult to believe that it has been carbonised at all (see Fig. 2A). Usually, however, the coke is much more open and cellular in structure than the original coal, but the shape has varied very little. The distortion becomes greater the higher the coking index of the coal used (see Fig. 2B).

It is hardly correct to term this coke a low temperature coke, for it has been heated to a temperature well above 600° C., and it has lost all the original volatile matter of the coal with the exception of from 3 to 4 per cent. It, however, ignites quite readily if the temperature has not been taken too high. The ease of ignition is apparently due to the porosity of the fuel, and not to the volatile matter remaining in the coke.

When the temperature is raised beyond a certain degree, a complete change takes place in the nature of the coke. The black colour of the easily ignited smokeless fuel changes to a silvery grey ; the ring of the coke when struck becomes more metallic ; the hardness increases slightly ; the ease of ignition departs, but the percentage of volatile matter changes so little during this physical change that the ordinary rough laboratory analysis fails to distinguish any difference in the percentage of volatile matter remaining in the two types of coke.

The quantity of gas made per ton of coal, however, regulates the type of coke produced ; black smokeless fuel being produced with a make of gas between 25,000 cubic feet and 30,000 cubic feet, and the grey type when the gas yields are over 30,000 cubic feet per ton of coal.

From the Scotch coals tested, which contained from 6 to 10 per cent. of moisture, and from 30 to 35 per cent. of volatile matter, about 55 per cent. of smokeless fuel has been obtained.

Gas.

Before coke is withdrawn it has to be cooled, and for this purpose steam is blown in at the discharging chutes. The steam

Coke Coal Coke

Fig. 2A

Fig. 2B

The above illustration shows the Glasgow plant during erection.

first cools the coke and is then itself decomposed into water gas, as it approaches the combustion zone. The calorific value of water gas is about 300 B.Th.U.s.

At the combustion zone, air at 60° C. saturated with water vapour maintains the temperature by burning out a portion of the carbon in the coke. Producer gas is made in this zone. This hot producer gas passing up supplies all the heat necessary for carbonisation. This gas has a value of 150 B.Th.U.s. or thereby. Above the combustion zone there is a zone where the fuel is between 750° C. and 500° C., and here some ammonia is generated. Above this zone the coal is giving off oil and gas, and this is termed the distillation zone. The gas given off has a high calorific value, possibly 700 to 800 B.Th.U.s., but the volume is relatively small. This gas mixes with the producer and water gas made below, and after passing through the coal in the condenser, where much of the oils condense out, passes down the annular space between the two cylinders and then through the seal and coolers. The C.V. of the combined gases is round about 240 B.Th.U.s. The plant is guaranteed to provide gas varying within 5 per cent. of this value.

The volume of gas made is guaranteed to be not less than 25,000 cubic feet per ton of coal.

Oil.

In the upper regions oils are given off and pass upwards through the fuel at gradually decreasing temperatures. Little decomposition therefore takes place ; and in place of a benzenoid coal tar, a highly phenolic crude oil is obtained. This oil contains neither benzene, naphthalene nor anthracene. It has little or no petrol but contains paraffin and paraffin wax ; olefines ; some aromatic compounds ; basic bodies and phenols of known and unknown constitution.

The boiling point of this crude oil is rather high, and hence much of it is condensed on the cold fuel in the upper part of the plant.

The successful working of the Maclaurin plant is due to the provision that has been made to trap this condensing oil and prevent it running down some corner of the plant into the hotter regions below and thereby suffering decomposition, and eventually causing the whole mass of coal to be bound together into an impenetrable mass.

Oil with some water collects here and passes under the inner cylinder and overflows by the gas main. It also acts as a seal and so prevents the gas taking the shorter passage. The gas

has, therefore, to pass through the cold fuel before leaving the plant and in so doing is cooled down to about 70° C. Little heat is therefore lost, as both gas and coke leave the plant at comparatively low temperatures.

To avoid radiation losses the brickwork is made 18 in. thick with a special non-conducting brick on the outside; the whole being encased in a metal casing. The oil yield is from 14 to 20 gallons according to the coal used.

Ammonia.

Some ammonia is given off in the direct distillation of the fuel, and a further portion is made by the steam passing through the zone between 750° C. and 500° C. This ammonia is carried forward with the gas; part condenses in the coolers and part is carried forward to the scrubbers. The quantity obtained varies from 17 lbs. to 30 lbs., according to the quantity of nitrogen in the coal used. The ammonia liquor differs very materially from ordinary gaswork's liquor. It contains neither ferrocyanides nor sulphocyanides. It, however, contains a considerable proportion of poly-hydric phenols. These phenols give rise to pigments which are quite easily extracted. Three different pigments are obtained from this liquor: one is a black, the second a brown, and the third a green. This green gives good shades for distemper when mixed with zinc oxide or lithophone. It can be used also as a dye for wool and is very similar to resorcinal green.

Cohe Handling.

The cooled coke drops into a trolley running below the plant, which is elevated to the top of the coke bunkers, which have a capacity of 110 tons. The trolley is emptied on to Whitehall coke screens, and in this way the coke is divided into three sizes, each size going to its respective bunker. These bunkers lie over the railway, so that waggons can be filled direct therefrom.

The quantity of ash contained in the coke naturally depends upon the ash contained in the original coal used, but the ash is not equally distributed throughout the different sizes of coke.

When washed trebles are used, the percentage of ash in the coke nuts would agree very closely with what would be expected by calculation; but when large coal is used, of a low coking index, a considerable concentration of the ash takes place in the dust, and frequently in the smaller size of coke. With such coal the large coke is found to be much freer from ash than the other portions; for example, in three coals of this type the distribution of the ash was found to be as follows :—

	Ash.	Ash.	Ash.
Original Coal ...	7·83%	6·29%	8·68%
Large Coke	8·83%	6·48%	8·40%
Smithy Char ...	18·53%	20·00%	27·50%
Peas	7·40%	16·76%	12·44%
Breeze	36·30%	32·64%	33·14%

With higher coking coals this separation is not so marked as the fines are naturally bound together with the larger pieces.

The percentage of breeze, smithy char, and large coke varies with the type of coal used. With washed trebles there is not very much breeze produced, but when large coal is used a certain amount of breaking down takes place, and the proportions of large to breeze obtained from four tests dealing with 450 tons of coal were as under :—

Large	72·8%
Smithy Char	11·7%
Peas and Breeze	15·5%

The gas from the plant passes through a seal for safety, and then through two of Blair's special type Tubular Coolers ; thereafter the gas passes to two mechanical Maclaurin patent Centrifugal Scrubbers, manufactured by Messrs. Blair, Campbell & McLean, Ltd., Govan. In these scrubbers the gases come in contact with a very fine mist of liquor, which effectively takes out all the ammonia and any oil being carried forward by the gas.

The oil and liquor collecting in the condensers and scrubbers are run to tanks, where the oil sinks to the bottom and the liquor floats on the top. This liquor is continuously pumped through the two scrubbers. After measurements are made the oil and liquor are run off periodically to their respective tanks, where further separation is effected.

The gas, now cooled down to atmospheric temperature, passes through a suction fan and from this to a meter, then through an automatic seal to a gasholder. The gas will be used for heating vertical retorts in Dalmarnock Gas Works. A small portion of the gas, however, is by-passed through a second meter to a Bone-Court boiler capable of generating 3600 lbs. of steam per hour. This steam will be used for driving a 100 h.p. horizontal steam engine, and the exhaust at a few pounds pressure will go to the bottom of the producers for the purpose of cooling the coke and making water gas. For this purpose 500 lbs. of steam per ton of coal carbonised is being provided.

The steam engine is sufficiently powerful to provide all the requirements of the plant. This engine drives a main shaft which drives all the fans and pumps, and in addition drives a

dynamo. From this dynamo, current is taken to a switch board and from there distributed to the motors driving the elevators, conveyors and scrubbers. There will be a surplus of electric power available from the first battery and this will likely be used up in the gas works.

Breakdowns.

To avoid any chance of stoppage duplicate plant is provided wherever possible.

To provide against any breakdown in the steam supply a standby motor is installed, and this will obtain its current from the Corporation mains. Pressure fans and suction fans are duplicated, and a breakdown of one of these can be rectified by simply starting the second fan running.

A temporary stoppage in any one of the producer units will not be a serious matter as this would only mean a fall of 20 per cent. in the gas made, but as each unit can double its output of gas over a long period any deficiency can readily be made up, until the necessary repair is effected.

All that remains now is to consider the output and commercial results from the plant.

The guarantee provides that the plant being erected will at least give results equal to those obtained by the Glasgow Corporation's own chemists on their four days' trial of the experimental plant at Grangemouth. In this test they put through 82 tons of coal, and Mr. McLusky's report states : " It will be seen from the financial supplement to chemist's report that the figures agree almost precisely with those submitted by Mr. Maclaurin."

The coal used during the test was a Stirlingshire coal, 70 per cent. of which was in large pieces. The coking index was too low to make the coal suitable for use in coke ovens, being about 13.

The proximate analysis was :—

Moisture	7·70	per cent.
Volatile Matter	30·50	,,
Fixed Carbon	53·70	,,
Ash	8·10	,,
	100·00	,,
Sulphur	·65	,,
Specific Gravity	1·34	,,

Calorific Value—12,300 B.Th.U. per lb.—275·52 therms per ton.

The coke when sieved gave the following proportions of the undernoted sizes :—

Breeze through $\frac{1}{4}$in. mesh	9·02	per cent.
Peas through $\frac{1}{2}$in. mesh ...	6·92	,,
Smithy Char through 1in. mesh	10·56	,,
Large Coke	73·50	,,
	100·00	,,

The specific gravity of the oil was 1·032, and the distillation test on the separated oil was as under :—

Moisture	1·70	per cent.
0 to 120° C.	·64	,,
120 to 230° C.	5·47	,,
230 to 270° C.	14·14	,,
270 to 320° C.	16·08	,,
320 to 345° C.	9·96	,,
Pitch	48·50	,,
Loss	3·51	,,
	100·00	,,

The Analysis of the gas is given below :—

Carbon-dioxide	6·0	per cent.
Hydrocarbons	1·0	,,
Oxygen	·4	,,
Carbon Monoxide ...	15·9	,,
Methane	12·4	,,
Hydrogen	16·8	,,
Nitrogen	47·5	,,
	100·0	,,

The thermal efficiency on the test worked out at 88·75 per cent. when no deduction was made for the steam used. When allowance is made for the gas required for raising the necessary steam, the efficiency is reduced to 86·5 per cent.

Having told you the yields at Grangemouth, it is now desirable to consider the cost at which these yields are obtained. In the original estimates made out for Glasgow Corporation, the actual working charges were estimated to be 5s. 9d. per ton, and by adding 15 per cent. for depreciation, maintenance and repairs, this figure was brought up to 8s. 8d.

The capital cost of the plant being erected is, however, higher than the first estimates, but with this extra capital cost a considerable saving in working charges will be attained.

Calculating on the same basis as the earlier estimates, it is confidently anticipated that the capital and working charges, including rent, rates, taxes, insurance, general charges, stores and supervision will be less than the earlier estimate.

With coal at 20s. and all other charges amounting to 8s. 3d., the products obtained must yield 28s. 3d. to make the process economically sound.

This it will be seen can be realised with the by-products selling at the following prices throughout the year :—

REVENUE.

Coke, 20,078 tons at 28s. 6d....	£28,606
Oil, 569,400 gallons at 5d.	11,862
Sulphate of Ammonia, 282 tons at £7	1,974
Gas, 2,190,000 therms at 1d.	9,125
	£51,567

EXPENDITURE.

Coal, 36,500 tons at 20s.	£ 36,500
Labour and supervision	2,737
Rent, rates, taxes, etc.	2,737
Interest and depreciation	6,000
Repairs, stores and general charges	3,593
	£51,567

When the installation is doubled, and the present lay-out provides for this, the steam engine, generator, boiler, etc., having been laid down with this object in view, the interest and working charges per ton will be slightly less than for the present installation.

Some New Aspects of Low Temperature Distillation

by Mr. Harold Nielsen, M.Inst.Chem.E., F.C.S., A.M.I.Mech.E.

GLOSSARY

Fractions	are constituent parts of an oil mixture obtained at various temperature ranges by distillation
Primary Products	are the products first constructed by treating coal at the lowest temperature at which liquid products are formed.
Secondary Products	are obtained by subjecting primary products to a higher temperature, which causes further reactions, generally termed destructive distillation.
Flame Temperature	is the temperature to which the resulting products of combustion will be heated up by burning the material.
Reaction	may be termed the changes chemically or physically which take place when two or more elements are acting one upon another.
B.T.U. (British Thermal Units)	is the amount of heat required to raise 1lb. of water one degree Fahrenheit.
Therm	is one hundred thousand B.T.U.s.
KW. Hour	equals 1000 volts × 1 ampere × 1 hour, or 1000 amperes × 1 volt × 1 hour, both equal 1·36 electrical horse power hours.
Low Temperature Distillation	is a term defining the heat treatment of carbonaceous material by which it is aimed to obtain purely primary distillation products. The temperature does not generally exceed 600° C.
Sensible Heat Distillation	is a scientific heat-controlled process, by means of which the primary products are set free by subjecting carbonaceous materials to the direct action of an inert gas heated up to the required uniform temperature.

Introduction.

A great many people believe that Low Temperature Distillation is something like a conjurer's hat, out of which can be produced all sorts of valuable products which will effect a lightning cure for all industrial evils, and whereby electric power can be produced in bulk ; the navy can be rendered independent of foreign oil fuel supplies ; the sun made once more to shine brightly, and mountains of waste dumps be turned into gold.

There is no end to the statements as to what can be produced from all sorts of coal and shales under any conditions you like to imagine, in any form of retort.

The word " Retort " at once conjures up in the popular mind something in steel and bricks into which waste products are tipped, and to which taps are attached up the sides from which one can, at will, draw off road pitch, lubricating oil, fuel oil, gallons of petrol, aniline dyes, and from the top tap wonderful antiseptics ready for bottling. To any serious-thinking person this would seem somewhat exaggerated, but statements of this nature get abroad and it is surprising the number of people who, without the slightest previous knowledge or experience in distillation, either from a practical or a scientific point of view, dabble in this most difficult business and invent retorts and processes which are doomed to failure even before they are put on paper. Nothing is easier to do than to put a few lumps of carbonaceous material into an iron pot, and watch some oil trickle out of the condenser. It is something which at once grips the imagination of most people, and very few realise the difficulties when the question of practical and economic working crops up as it must do in the end.

Low temperature distillation is essentially a plain business proposition which must seriously be considered :—

Firstly, from the scientific side ;
Secondly, from the practical and the engineering ;
Finally, from the purely commercial point of view.

Naturally, the latter in the long run will be the most important for the general and economic welfare of this country as a whole.

The primary object of this Congress is to discuss the simplest way of eliminating the smoke nuisance, and

of making the air more healthy for human beings. Economic questions of the greatest importance are intimately connected with this, and if the smoke abatement campaign is to succeed it is of paramount importance that distillation should be made a paying proposition ; if not, the greater portion of householders and industrialists will treat the matter as a " something which would be rather good if it eventually could be accomplished, but for the present, let us just carry on in the old way."

General Remarks.

I have stated that low temperature distillation is essentially a business proposition, and as such the standard laws of supply and demand are the governing factors. The products produced must be sold in competition in the open market with similar products from other sources, and with the raw material from which the products are extracted.

The solid residue, which is generally by far the largest percentage, must be sold at a price which renders it attractive to the manufacturers and householders alike, irrespective of its smokeless combustion and other virtues ; and here it must be stated that the original raw coal is the most formidable competitor, consequently the sale price for the solid residue must not be higher than that of the raw material. The man in the street will never believe that the mere fact of removing some valuable products from the fuel will justify a higher price for the residue, it is more likely to be the other way about.

Then there are the oils ; here again the market prices for " well oil " and " gas works tar " will be the governing factors.

To-day nobody can state the true value of low temperature distillation oils, as far too little research work has been carried out on them. A mere fractionating is no guide whatsoever ; degree of saturation may tell us something, but not much. Many get enthusiastic over a somewhat high yield in lighter fractions, while possibly the heaviest lubricating and grease fractions may prove by far the most valuable. We must realise that present-day knowledge of low temperature oils is still in its infancy, and it must of necessity take a considerable time before the low temperature liquid products are understood to the same extent as high temperature products.

We must also give up the fallacious idea that any large yield of sulphate of ammonia may be reckoned on to

swell the budget when low temperature distillation is employed. At the most a few pounds can be obtained, and it is doubtful whether the recovery will pay in other than a few isolated cases.

The gas obtained will form a source of revenue, but any extra large yields in conjunction with a large stated oil yield must be looked upon with suspicion. It must be remembered that most of the illuminating and high calorific value components of the gas are due to the secondary decomposition of the original liquid primary products, so of necessity a large gas yield spells a lesser oil yield ; and when working under proper low temperature conditions, 3000 to 3500 cubic feet of gas is the most that can safely be reckoned upon. The introduction of the therm has added an enhanced value to the low temperature gas whenever there is a sale for the gas as a town gas.

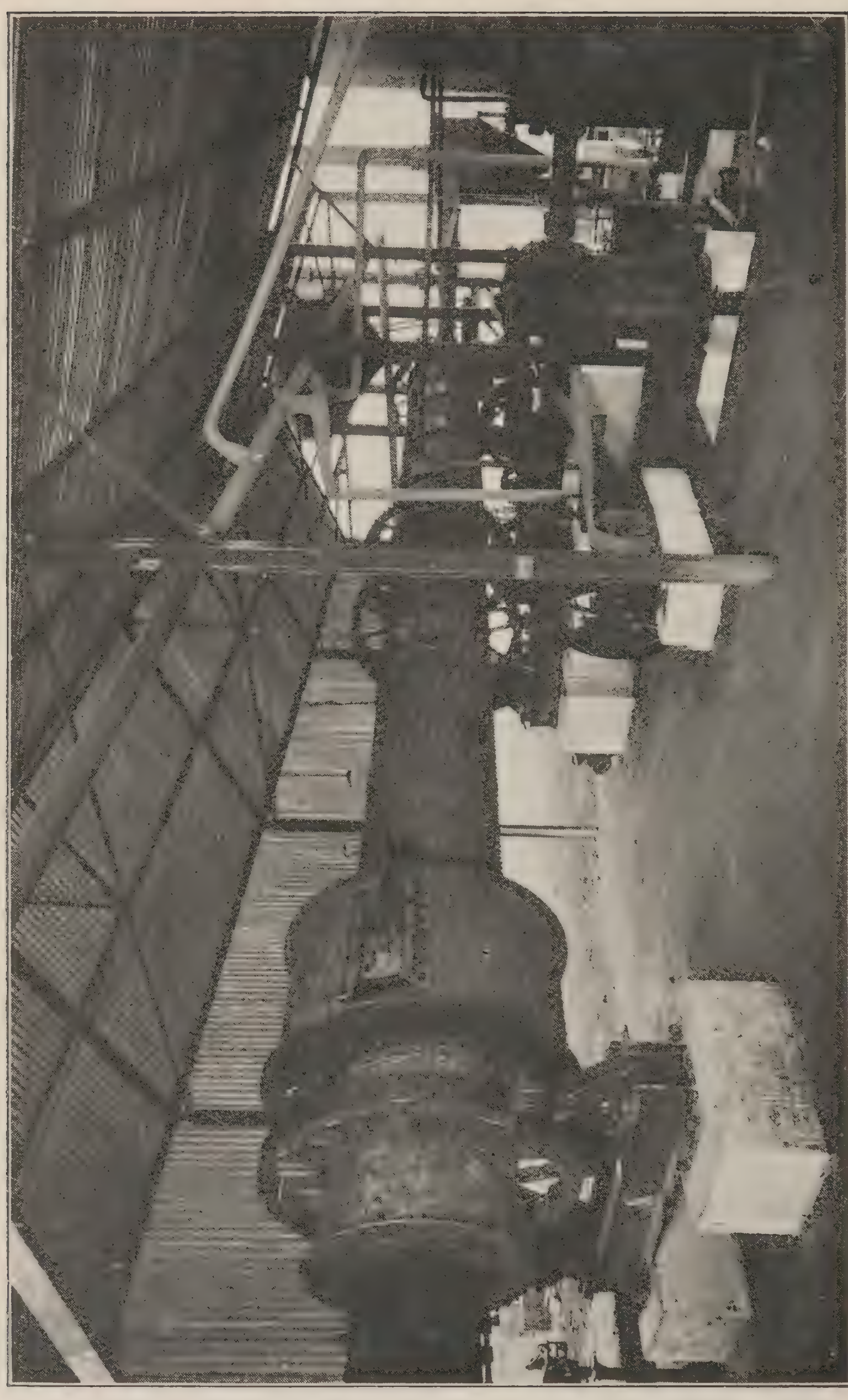
Economic Question.

Bearing the above considerations in mind, it should be possible, with a fair degree of accuracy, to say whether any low temperature scheme would have a chance of being an economic success in any particular locality. It is the production cost which at all times will be the dominating factor.

In my paper before the South Wales Institute of Engineers, in April, 1922, I drew specific attention to this, and tried to prove that unless this figure is low, the economic success of any low temperature distillation process is highly problematical. It will take too long to go into details of the production costs here, but it will suffice to say that the overall costs to-day per ton of raw material treated, including :—

Depreciation on capital cost, including foundations and buildings and complete plant,
Fuel for carbonising,
Cost of handling material,
Power and steam,
Labour,
Maintenance and stores, etc.,

should not exceed 4s. per ton, excluding briquetting if necessary. The capital cost, including everything, should not exceed 10s. to 12s. per ton of raw material dealt with per annum.



View showing Rotary Retort "L & N" Process.

Few technical problems can rightly be said to offer more scientific difficulties than low temperature distillation, and the sooner this elementary fact is realised the better. On the other hand, few problems have in the past been so confidently faced with such appalling ignorance.

I wonder if it is generally realised that nobody knows what a piece of coal really is! We can tell what percentage of carbon, hydrogen, oxygen, nitrogen, sulphur and ash it contains, but this only by complete destruction of one of the greatest wonders of nature in existence. It is realised that up to date about 60,000 different compounds are known, composed of carbon in combination with some other simple elements. Does the average man appreciate that you can treat a lump of coal in a hundred different ways, and get a multitude of different products? People talk about "certain oil fractions." There are scores of different compounds in one single fraction. Is it generally realised that a few degrees of temperature will completely alter the delicate building-up machinery of the carbon compounds?

I firmly believe that, until science in all its branches is brought to bear on this subject, we shall not be many steps advanced towards a final solution.

So far we can probably say, with certainty, that although no two coals can be treated alike in order to yield the best products ultimately desired, it is possible to lay down certain elementary rules and regulations, which I shall here enumerate and call them the Axiom and Ten Distilling Commandments.

Axiom.

In the past, Destructive Distillation has been the Principle—in the future, Constructive Distillation must be the Policy.

The Ten Commandments.

I. From an economic point of view, the raw material must be treated in bulk.

II. Any desired reaction temperature must easily be attained and be kept with a minimum of variation.

III. Strict temperature control.

IV. Rapid and uniform treatment so as to obtain a maximum throughput.

V. Lowest possible distillation temperature in order to secure the products in the primary state and avoid secondary reaction.

VI. Absolute control of time-duration in the various temperature zones.

VII. Countercurrent principles strictly adhered to, so that once an oil vapour has been evolved at a specific temperature, it should not be brought into higher temperature zones.

VIII. Rapid removal of distillation products once they have been formed.

IX. The retort should only be called upon to act as an economical and efficient separator of solid, liquid and gaseous products from any raw carbonaceous material, this being its primary function.

X. The treatment should aim at being continuous; continuous feeding, heating and discharging.

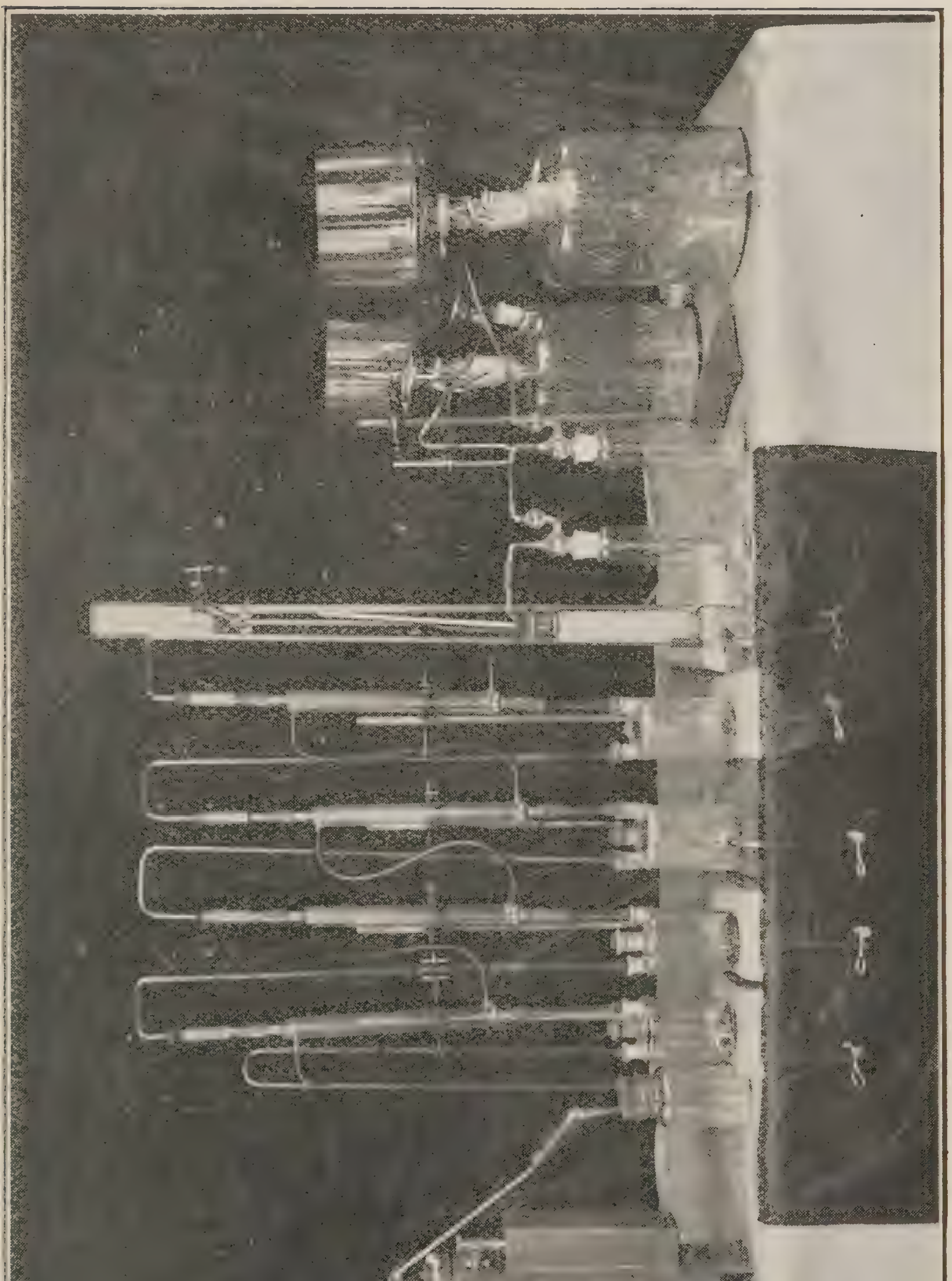
No single commandment can with impunity be sinned against without affecting the efficiency unfavourably.

Assay Plant.

It is not possible to say definitely, according to a small scale test, how and what might be recovered on a much larger scale unless the small test or assay is carried on under the same temperature and time conditions as the commercial units. Tests where external heat is employed do not give any reliable data whatsoever for internal heating, or even for external heat application unless the conditions outlined above are identical.

I claim to be more or less the pioneer of low temperature distillation in rotary retorts by means of the sensible heat of an inert gas, and I have found that existing assay methods do not give me any analogous result compared with large scale operations. So I set out to make an assay plant to give me comparable data, and I have had a certain measure of success. I am now running my assay tests in parallel with my large scale operations, and I obtain very good agreement.

This assay method opens up the possibility of conveniently studying low temperature distillation and



View showing "L & N" Assay Plant

predicting what may reasonably be expected on a large scale, in fact, it acts as a laboratory control. How important an efficient laboratory control plant is need hardly be emphasised.

These few remarks have perhaps brought home to you that successful low temperature distillation is something which requires all the combined resources of science and engineering available in the country, and that no single man or corporation can justly lay any claim to solve this stupendous question in all its branches. All that can be claimed is that useful knowledge has been advanced a few steps.

Difficulties of Distillation.

Let us for one moment see what we have to contend with when distilling coal under low temperature conditions. Firstly, coal and most carbonaceous materials are notoriously bad conductors of heat ; for instance, at an initial temperature difference of 200 to 250° Centigrade the penetration rate of heat is only 0·75 to 1·00 inch per hour, and as the heating goes on, so the temperature difference gradually decreases with a consequent slower heat flow, and you will, therefore, appreciate that a coal thickness of 4 inches requires about 5 to 6 hours before being completely carbonised. The heat flow in a given time can very materially be increased by raising the temperature, but by doing this we would get beyond the low temperature distilling range, and decompose our primary products. The only other alternative is to multiply the heating surface, or by decreasing the thickness of the layer of material, but when employing external heat, practical difficulties soon put a stop to expansion in these directions.

The one way still remaining is to surround the coal particle with a hot inert medium, and transfer the heat from the same direct to the coal. I have done this, and I apply the heat internally without any intervening walls, and am now in a position to overcome successfully the bad heat conductivity of the coal. I have increased the heating surface of each single piece of coal. By crushing the coal to small sizes, the distance the heat has to penetrate from the outside to the centre of the various single particles can be made as short as desired. By going to extremes and grinding the material finely, the distillation can be done almost instantaneously, *i.e.*, a few seconds only will be required, or, in other words, the temperature difference need only be slight, as the distance to be traversed by the heat is very short.

It will now be clear that the temperature at which the distillation is effected can be brought down to the desired extent without fear of prolonging the operations, and subsequent secondary decomposition is avoided.

My retort does not act in the same way as by external heat application. It serves merely as a container for the carbonaceous material in bulk and the heating medium. It, therefore, stands to reason that the larger we make the container, the more raw material, with a proportionately larger heating surface, can be passed through, simply by increasing the volume of heating medium without altering the distilling period or the temperature range.

The problem of maintaining the most suitable temperature becomes a much more simple proposition, particularly if the generation of the heating medium be done in a separate apparatus apart from the retort, so that the working of the latter can be carried out independently, and feeding and discharging done without interfering with the heating medium. Again, the heating medium can be produced and adjusted without interference from the material passing through the retort.

"L and N" Process.

It might be of interest to explain how the firm with whom I am associated carries out low temperature distillation.

We employ a slowly rotating, inclined retort, somewhat similar to a roasting or calcining furnace. The raw carbonaceous material is continuously fed into the top end of the retort and travels slowly downwards towards the automatically-controlled exit, which is arranged so as to form an air-lock, allowing the residue to be discharged after cooling to the outside atmosphere, but preventing the outside air from getting into the retort.

The hot distilling medium enters the lower end of the retort and travels in counter-current, and is in direct contact with the material to be treated ; it heats the same up to the proper temperature very gradually and evenly, and finally escapes, carrying along with it the permanent gases and condensable matters evolved from the carbonaceous material.

It naturally depends upon local conditions what kind of heating medium is employed. We claim that our

distilling process is particularly applicable to a great number of projects, too many to go into in detail here.

Domestic Fuel.

Take as an example the production of a smokeless domestic fuel, with which we are here mostly concerned. In connection with this I would like to draw attention to the erroneous belief which is unfortunately generally held, namely, that a free burning, smokeless fuel can readily be made from almost any raw material ; this, unfortunately, is not so. There are natural fuels, such as anthracite and certain low volatile steam coals, which are practically smokeless, as we all know. Then there are volatile or bituminous coal, which can be treated in ordinary coke ovens and produce a smokeless coked residue for burning in closed furnaces. Then we have some classes of gas coke for which it is claimed, rightly or wrongly, that the particularly porous structure makes the coke free burning under almost any conditions, in spite of a very low percentage of volatile matters.

Finally, we have the vast amount of non-coking bituminous coal, which will not on treatment form a coherent residue of suitable size for the domestic grate. Briquetting has to be resorted to, and as the so-called binder is generally pitch, it will be understood that the smoke once removed by the distillation is again added in the form of pitch, so very little is eventually gained. There is a new smokeless binder, however, which, if the promises hold good, will bid fair to develop into an industry of the greatest importance, in conjunction with an efficient distillation plant.

With regard to the direct production of a smokeless domestic fuel by low temperature distillation, without subsequent briquetting with a binder, we are limited to the use of coking bituminous coal; and, further, we have only a narrow choice within these coals, as the mere fact that a coal will produce a high grade high temperature coke is no criterion that it will produce a good carrying smokeless low temperature fuel.

It might be said that the surplus coking power of strongly swelling and frothing coal, could be utilised for blending with slightly caking or non-coking coal, whereby a good carrying fuel would result ; but it must not be lost sight of that it is very rarely the case that two such suitable coals are found in the same colliery.

Briquetting.

There is, however, another way which is being closely investigated, and if our expectations are fulfilled will be a step towards the solution of this most intricate problem.

About four years ago we observed, during a test run with our first experimental retort, that some carbonaceous residue appeared, as if a preliminary heating and briquetting in the hot state without binder, followed by a final distillation, might produce the desired result. I am pleased to say that experiments carried out by us, by the Fuel Research Board and others, hold out considerable promises in this direction.

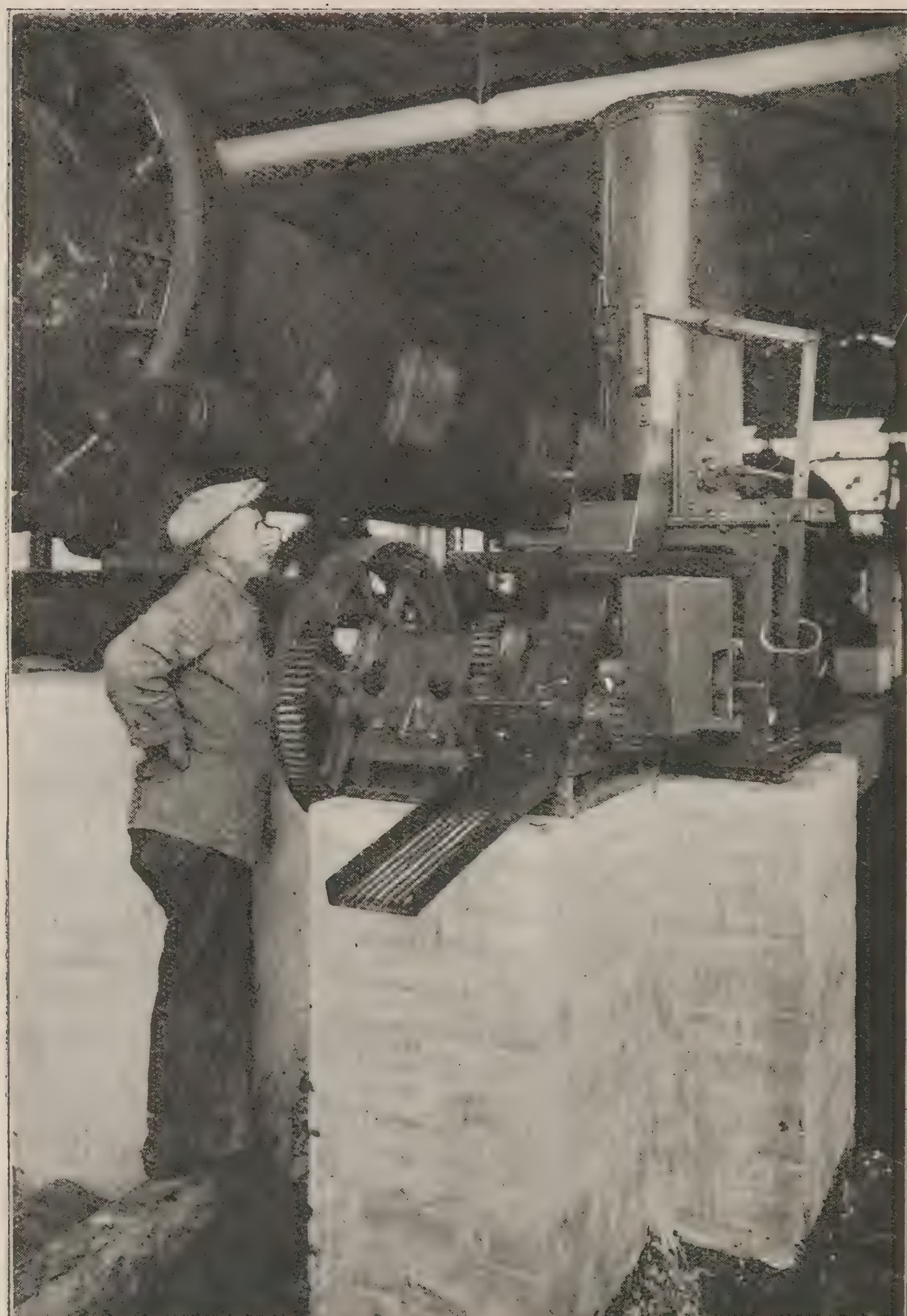
A smokeless, uniform briquette of 2 to 4-ounce ovoid form, made in the way roughly outlined above, is a step in the forward direction, and we have now installed the very latest type of Continental briquetting plant, working according to a new, most ingenious principle in conjunction with our retorting installation at the Old Silkstone Collieries.

Powdered Fuel.

Although the domestic chimney is justly blamed for creating most of the smoke nuisance in the London area, the industrial smoke stack in the manufacturing part of this country easily beats the domestic one. I am not in a position to say that smoke can be absolutely avoided in all cases, but manufacturers have almost forcibly to be shown how to do so and thereby save money. They are in a much better position to burn coke than householders. Modern mechanical or underfed stokers, chain grates or step grates, will burn this material of any size to almost fine breeze.

Powdered fuel-firing has come very much to the fore lately, and the new super-power stations in America and on the Continent are being equipped with powdered fuel appliances. Raw coal can be burnt practically smokelessly in this manner. There are, however, a great number of manufacturers who would willingly consider a powdered fuel installation, provided all danger of explosion and spontaneous combustion could be eliminated. Bearing in mind the accidents which have happened in the past, and the risks that are still incurred owing to the highly inflammable and explosive fine coal dust, there is something to be said for this.

Let us draw a parallel between raw coal dust and the crude paraffin or colza oil our grandfathers used to burn



View showing Briquetting Plant

in small lamps. It was with grave apprehensions they lit their little lamps, very often they (the lamps) went up with a bang, and it was not until the flash point of the oil was raised by refining and the removal of the lower boiling point fractions that the paraffin oil lamp was made safe.

Exactly the same applies to powdered raw coal; you have here a mixture of highly volatile matters in an easily oxidised state, hence the danger. Remove the same by distillation and the carbonaceous residue will be as safe to handle as fuel oil. It is stated that a small percentage of volatile matters left in the carbonaceous residue is ample to maintain the flame propagation in the furnace, the balance of the original volatile matters are recovered as a highly useful oil and gas. The latter can be used as a pilot flame for the powdered fuel furnace where the distillation is done on the spot.

The possibility of erecting central distillation and pulverising works, supplying a standard grade of pulverised fuel over certain areas, now becomes perfectly feasible. The powdered semi-coke is absolutely dry as it is not subjected to water quenching by the "L and N" process, and can be stored in silos for any length of time without fear of spontaneous combustion. It does not oxidise to any extent, and can be shipped in tank waggons, pumped and handled exactly like liquid fuel.

We are convinced that, taking credit for the distillation products and gases, it should be possible by our process to supply broadcast a powdered fuel, heat unit for heat unit at the same price as the raw coal, so that the manufacturer makes an extra profit by the increased efficiency and the labour saved in the boiler house.

With a safe powdered fuel, another interesting proposition is opened out for us: oil burning for ships is going ahead at a pace which was inconceivable a few years ago. Why should powdered semi-coke eventually not come into its own in this particular sphere also? Powdered fuel can be pumped like a liquid. It could be pumped from tank waggons or tankers into ships or locomotive bunkers. The stokehold will be just as tidy and neat as with oil-firing, no more labour is required and the boiler flexibility is, if anything, greater. Compare the difference in running costs:—

Fuel oil at, say, 16,000 B.T.U. per lb. costs £3 10s. to £4 per ton.

Powdered coal, 12,000 to 13,000 B.T.U. per lb. costs 17s. 6d. to £1 per ton.

Smoke from the steamers in harbour would be abolished, and, finally, the oil-burning steamer throwing 100 to 150 miners and labourers permanently out of work would be replaced by one burning powdered fuel.

What will eventually happen to the miners if something is not done to prevent all ships becoming oil burners ?

The solution lies in these few words "*efficient coal distillation and efficient use of all the products obtained.*"

It may sound very strange to-day to propel ships with powdered fuel, but remember that the thing which appears to be improbable to-day is the established fact of to-morrow. In this respect we have the support of one of the largest steel, coal and shipowning firms on the Continent.

Gas for Furnaces.

I have dealt at some length with the solid residue, as this is by far the largest percentage of the products obtained, and I shall only mention that a still further use will be found for this material. To-day's English steel prices are considerably higher than foreign prices, sometimes as much as £2 per ton.

In my opinion, although short hours and high wages play a considerable part in this, is it not a fact that the cost of the fuel is by far the largest item in the cost of manufacture, and that any considerable reduction in the same will have far-reaching effects ? Cheaper raw coals, once they have been treated by an efficient distillation process, are just as efficient for producer gas manufacture.

The only reason why more expensive coals are used is because they work better in the producers, while cheap duff and smalls of the same heating value are useless.

By distillation and hot briquetting, as I have described, smalls can be made into a perfectly uniformly-sized producer fuel ; and, what is still more important, the distillation gases from the retort will enrich the producer gas, so that from a ton of rough smalls and slacks about 100,000 to 110,000 cubic feet of gas will be produced of a much higher calorific value, namely, about 180 B.T.U. per cubic foot.

I wish to lay particular stress on the following. When the reaction temperature of the molten metal bath approaches the temperature of the flame employed, any higher flame temperature will effect a saving in fuel far out of proportion to the relative quantities of fuel used. An increase in flame temperature due to, say, 5 per cent. higher B.T.U. value of gas, may easily effect a saving of 10 to 15 per cent. in fuel consumed. This is a generally admitted fact. The only question has been how to obtain the extra 5 to 10 per cent. higher B.T.U. value of suitable gas of the proper analysis economically ; we claim that by our distillation process it can be done, and I might here say that in this contention we have the support of some of the foremost steel people in this country and abroad.

The one way to produce cheaper steel is firstly to use cheaper fuel, but in a more highly concentrated form, *i.e.*, higher B.T.U. value gas ; secondly, to recover as much oil as possible by the distillation and to take credit for this in the fuel cost. The net result will be that the British steel manufacturer will once more compete in the open market without cutting wages.

Strictly speaking, the above is not relevant to smoke abatement unless the increased use of gas furnaces is taken into consideration.

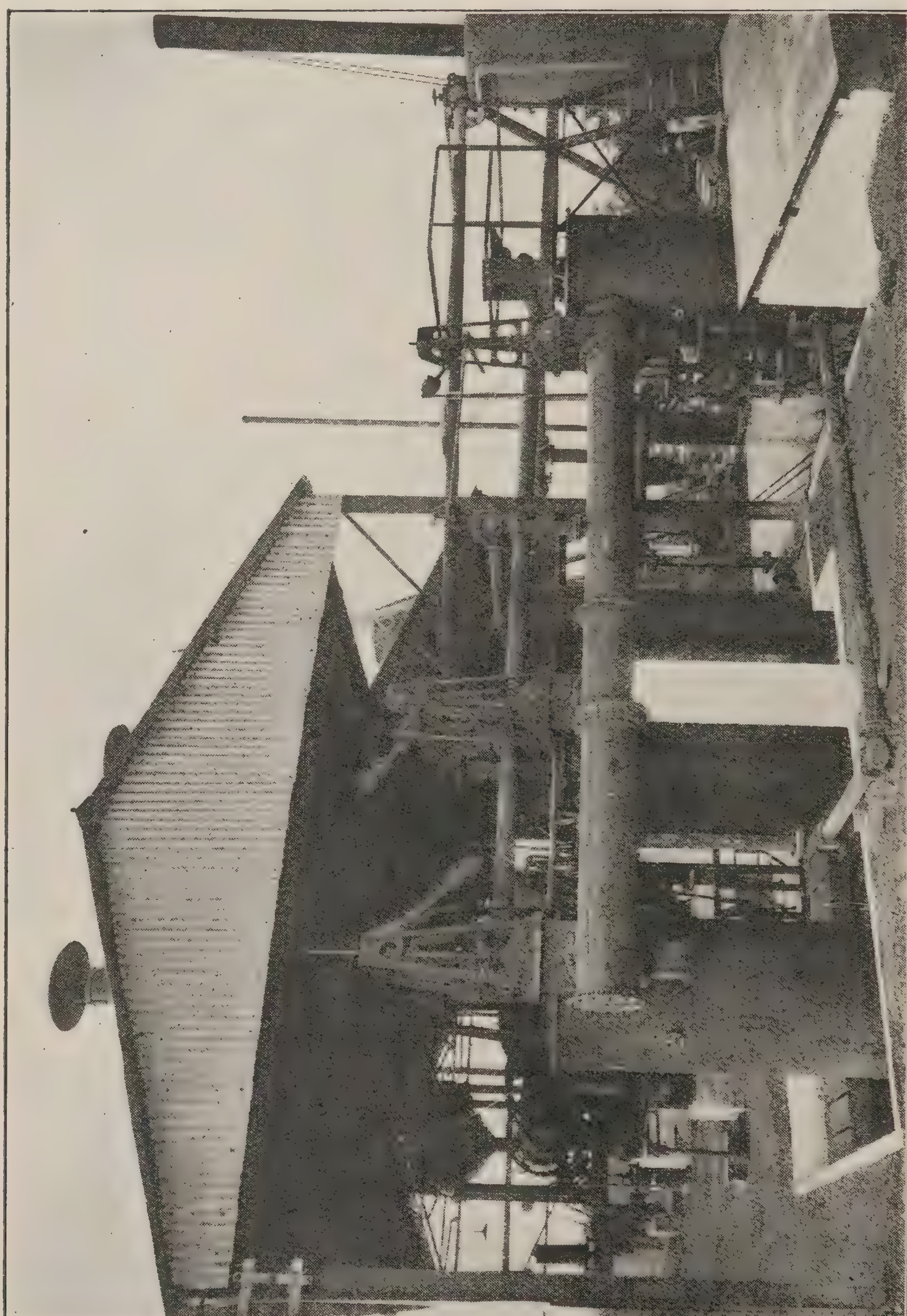
Town Gas.

To revert to the domestic use of fuel, undoubtedly town gas at the present time is the most important.

The reason why town gas is perhaps not used to the extent it deserves is due to the comparatively high price of the B.T.U. in gas form, about 8d. to 9d. per therm as against the B.T.U. in solid form, say 1·5d. to 1·6d. per therm, in both cases delivered.

If the price of the gas therm can be brought down to, say, within 200 per cent. of the solid therm, the use of gas will most certainly increase enormously. It is *only* a question of how to produce the therm for less than half of the present price. In order to do this, the plant must cost less, labour must cost less, more by-products must be recovered, and, finally, cheaper grades of coal must be used.

To carry this out, we must turn to complete gasification in conjunction with low temperature distillation. It must be borne in mind that :—



View showing Water Gas Producer and Regenerator

(*a*) A gas must be made which is high enough in B.T.U. value to allow the present service main system and house fittings to be used, so that the necessary volume of heat will be available at any desired spot.

(*b*) For obvious economic reasons oil carburetting must be avoided.

The heating value of ordinary straight complete gasification gas is generally not more than 360 to 370 B.T.U. This gas, although excellent for most purposes, is considered too low for efficient supply through existing mains in large towns, the lower limit may be said to be about 420 B.T.U. per cubic foot.

By ordinary straight complete gasification, this higher value gas cannot be produced in one stage in a single superimposed retort and water gas producer unit. We realised the futility of this very quickly.

This problem can, however, be solved by the application of our system, working a three-stage process in the following cycle :—

(1) Gasification of the solid residue in water gas producers.

(2) Distillation of the raw coal by superheated straight or so-called blue water gas, resulting in a mixed gas of 360 to 370 B.T.U. per cubic foot ; the total residue from this distillation is then converted into water gas, the blow gas being used for heating the regenerators.

(3) After oil absorption from the mixed gas, this is again superheated and effects a further distillation of raw coal, the solid residue from the second distillation forming a smokeless fuel for sale. The gas now, after oil scrubbing, has a value of 420 to 430 B.T.U. per cubic foot.

What in reality has taken place is that ordinary water gas has been " carburetted " with raw coal twice.

To place some figures before you I will say that from two tons of raw coal there will be produced :—

44,000 to 45,000 cubic feet of gas at 425 B.T.U.;
38 to 42 gallons of crude paraffin base oil ;
0·75 to 0·78 ton of smokeless fuel ;

and the sale price of the gas to the consumer, when taking credit for the oils and smokeless fuel at competitive prices, will not exceed 5d. to 6d. per therm.

The gas companies would be the best distributors of the resulting smokeless fuel.

Electrical Energy.

In an article in the *Gas Journal* during 1920, I suggested that municipal gas undertakings should be linked up with electrical generating stations, and far more efficient use be made of the blow gas from the water gas plants; at present the avoidable waste represents about 25 to 30 per cent. of the heat value of the water gas producer fuel. This otherwise waste heat is excellent for steam generation and would produce from 100 to 120 KW. hours for every ton of coal gasified.

If the water gas producer be run on slightly different lines so as to make a higher value blow gas, as I once stated, the electrical production is still more startling.

I was very gratified to see that the well-known Professor Stracke, of Vienna, at the World Power Conference, made exactly the same proposal.

Utilisation of Sewage.

Smoke abatement, as we discuss it here, has such an important bearing upon the health of the community, that I feel that it will not be out of place to mention another matter of grave concern to the health authorities, and where low temperature distillation will be of the utmost service in solving a question which is getting more and more serious in many industrial localities to-day. I am referring to the disposal of sewage.

It sounds incredible that low temperature distillation can turn this material to profitable account. We have considered this matter carefully, and on the basis of tests we have carried out in our assay retort we are in a position to state that it is possible to recover at least 18 to 20 gallons of oil per dry ton. This oil must not be confused with mineral oils, as sewage oil is an animal and vegetable oil, worth much more than mineral oil, and forms an excellent basis for high class lubricants and other products.

In the London area many million gallons of oil can be recovered annually from this material. The solid residue will form a basis for fertiliser manufacture, containing as it does 3·5 to 4 per cent. of calcium phosphate.

To-day the disposal costs of sewage cake, in the London area, exceed five shillings per ton. This amount will cover the cost of the treatment.

I hope that in the preceding pages I have given you ideas respecting some new aspects of low temperature distillation, of which hitherto little has been said and published.

Scientific Research.

We realise that we are on virgin soil respecting tests and investigations, and we also realise that we must proceed step by step, consolidating the ground as we go ahead, check, control and verify all observations before anything is made public property.

We also know that the problem of low temperature distillation is too far-reaching for one group of people to attempt to solve it in all its various branches, so for that reason we have allied ourselves with eminent people in this country and abroad, and we are endeavouring to institute team work, as on these lines alone can success hope to be achieved.

Conclusions.

Finally, may I say that the successful distillation of the carbonaceous materials of Great Britain will lead :—

Firstly, to more employment due to the manufacture and working of distillation plants for carry-out this object.

Secondly, to more coal being mined for the purposes of producing the oils, etc., that this country requires.

Thirdly, to smokeless fuel being available for household purposes, steamships, locomotives and factories.

Fourthly, to gas for town purposes being produced at considerably lower prices, thereby increasing the demand.

Fifthly, to electrical energy being generated at a figure which will compare favourably with electrical energy produced by water power.

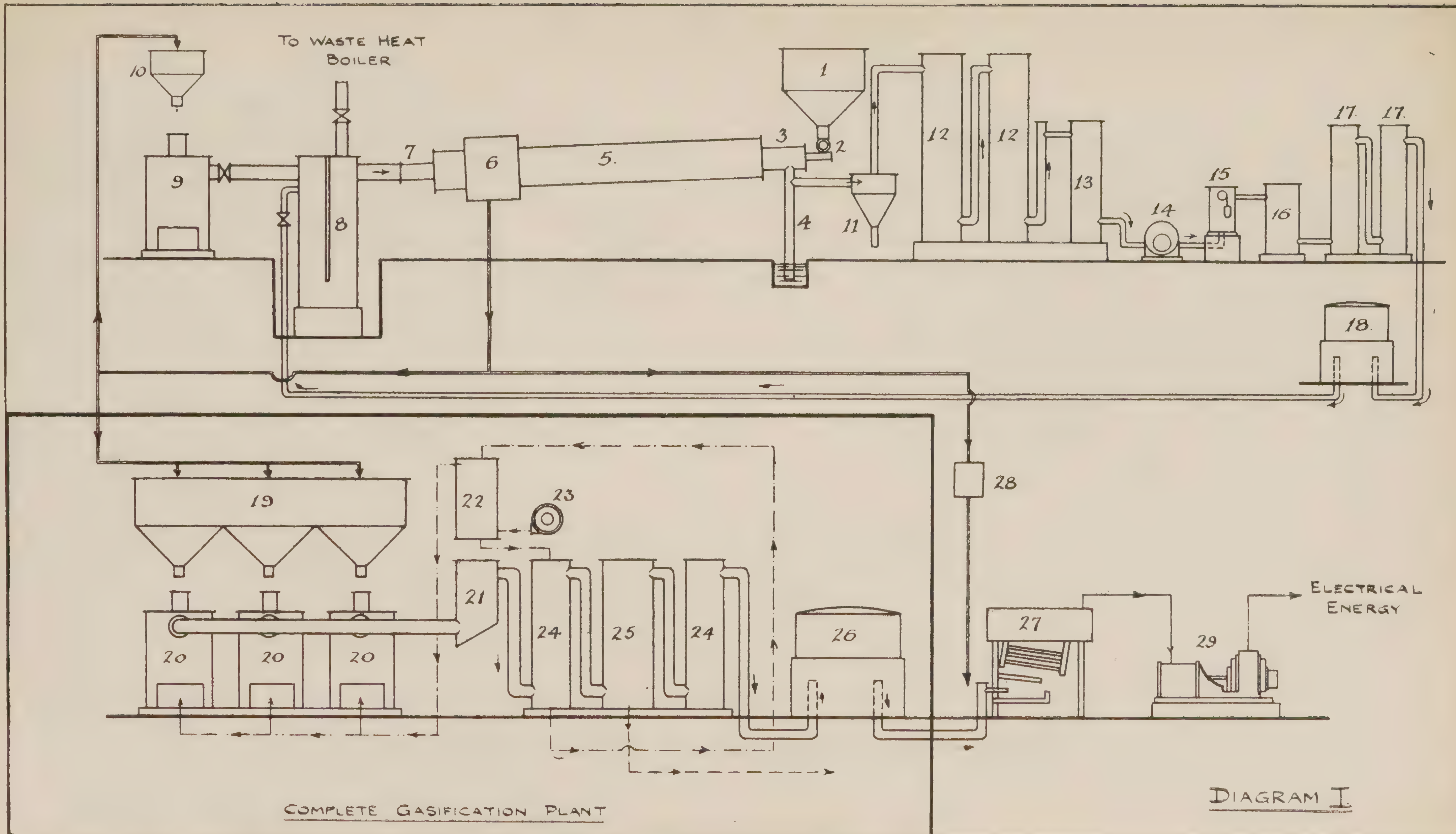
In fact, it will mean that the natural wealth of the country will be turned to profitable account, unemployment will diminish, the country itself will become healthier, happier and brighter, and the credit of this will largely be due to the efforts and support of the Smoke Abatement Committee, in conjunction with the Ministry of Health.

In conclusion, I, personally, must thank those with whom I am associated for their valuable aid during the experimental periods of Sensible Heat Distillation.

The Production of Power Gas—Key to Diagram I

Water
Sulphate Liquor
Air
Smokeless Fuel

1 Coal hopper
2 Coal feeding device
3 Gas outlet pipe
4 Explosion seal
5 Rotary retort
6 Coke cooling chamber
7 Gas inlet pipe
8 Regenerator or super-heater
9 Producer
10 Producer fuel bunker
11 Dust extractor
12 Air-cooled condensers
13 Water-cooled condenser
14 Exhauster
15 Heavy oil extractor
16 Final gas cooler
17 Light oil washers
18 Gas holder
19 Smokeless fuel bunkers
20 Producers
21 Super heater
22 Air saturater
23 Fan
24 Gas washers
25 Sulphate tower
26 Gas holder
27 Water tube boiler
28 Pulveriser
29 Turbo-generating set

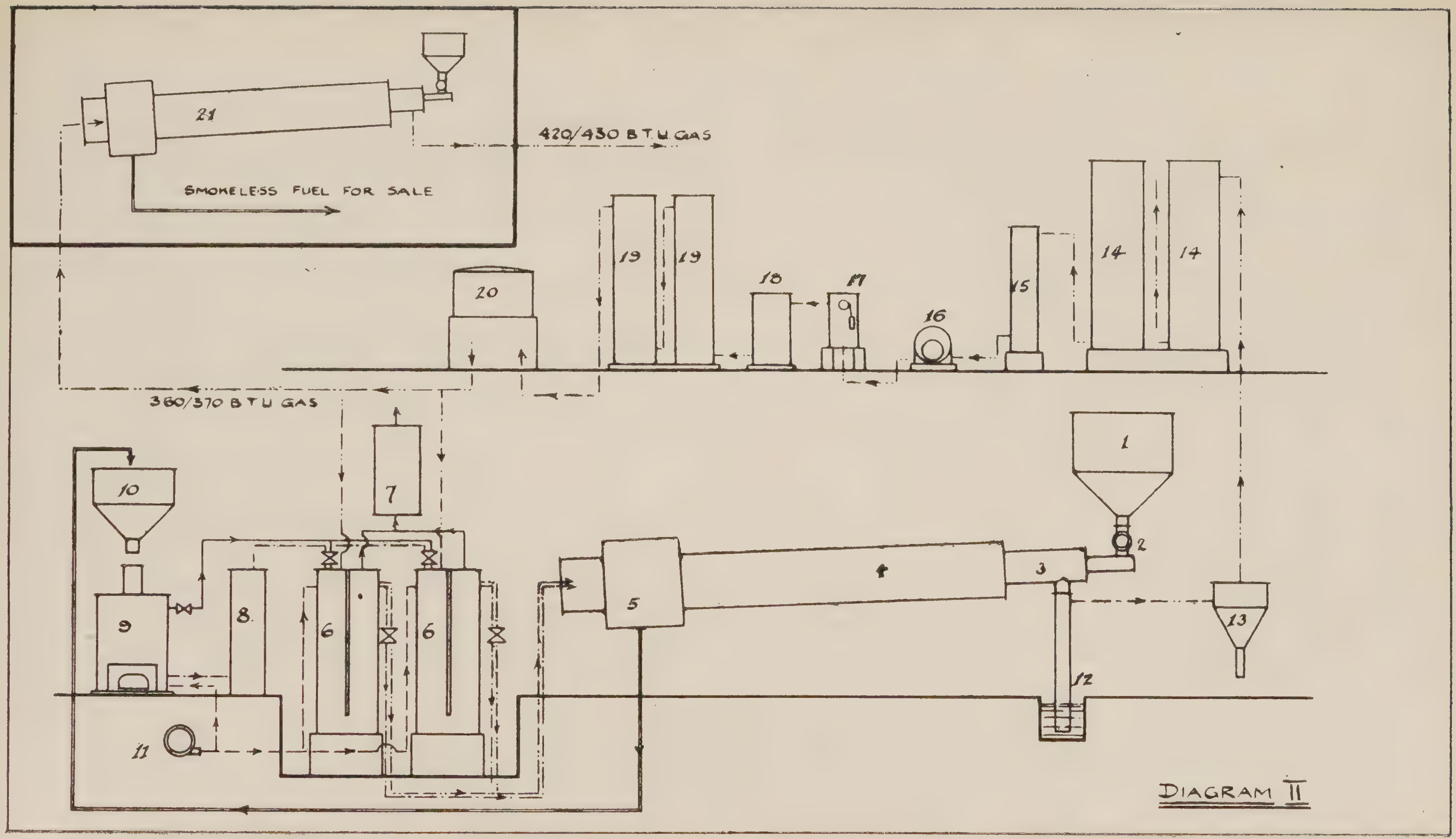


Flow Diagram of Plant for the production Power Gas

The Production of Town Gas—Key to Diagram II

————————	Blow Gas
— . — . — .	Water Gas
— — — —	Air
— — . . — —	L.T. Gas
════════	Smokeless Fuel

1	Coal hopper	12	Explosion seal
2	Coal feeding device	13	Dust extractor
3	Gas outlet pipe	14	Air-cooled condensers
4	Primary rotary retort	15	Water-cooled condensers
5	Coke cooling chamber	16	Exhauster
6	Regenerators or super-heaters	17	Heavy oil extractor
7	Waste heat boiler	18	Final gas cooler
8	Water gas washer	19	Light oil washing towers
9	Producer	20	Gas holder
10	Producer fuel bunker	21	Secondary rotary retort
11	Fan		

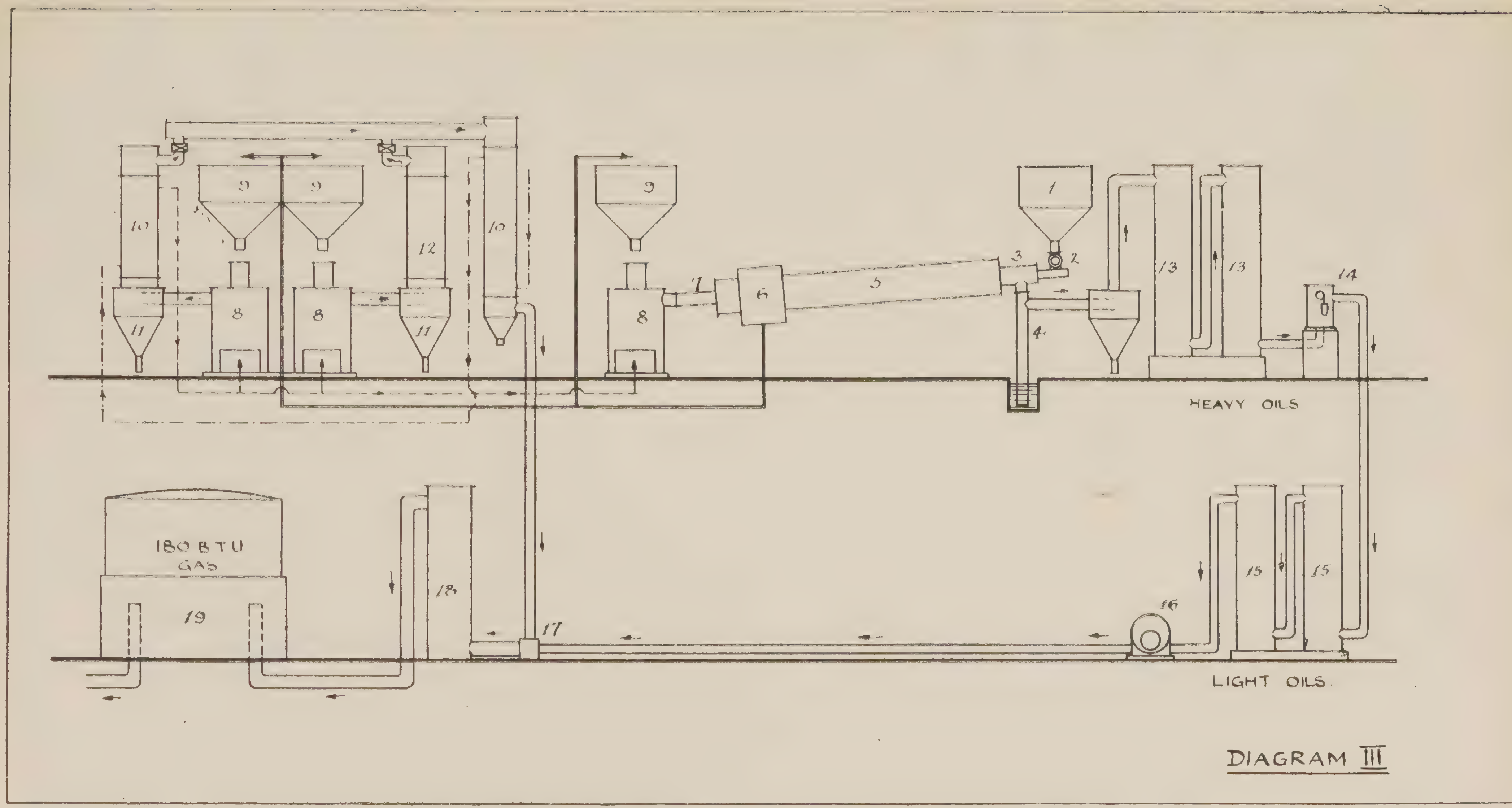


Flow Diagram of Plant for the production of Town Gas

Production of Gas for Steel Works—Key to Diagram III

Smokeless fuel
Steam
Water

1	Coal hopper	11	Dust extractors
2	Coal feeding device	12	Waste heat boilers
3	Gas outlet pipes	13	Air-cooled condensers
4	Explosion seal	14	Heavy oil extractor
5	Rotary retort	15	Light oil washing tower
6	Coke cooling chamber	16	Exhauster
7	Gas inlet pipes	17	Injector mixer
8	Producers	18	Final gas washer
9	Producer fuel bunkers	19	Gas holder
10	Economisers		



Flow Diagram of Plant for the production of Gas for Steel Works.

"Coalite"

(Low Temperature Carbonisation Limited)

by The Rt. Hon. George H. Roberts, P.C., and P. C. Pope.

The importance of the subject under discussion is such that we need no excuse for repeating a statement often made before, that the practical solution of the problem of Low Temperature Carbonisation of coal is the most important scientific event in the industrial history of this country since the invention of the steam engine ; meaning as it does to Great Britain a saving of about £200,000,000 per annum, and the production within our own boundaries, and by the employment of British capital and labour, of a home supply of motor spirit, fuel oil, lubricating oil, and Diesel oil, together with sulphate of ammonia for the cultivation of the soil, in addition to the abolition of black smoke by the use of smokeless domestic and industrial fuel.

The Mines Department and the Department of Industrial and Scientific Research issued a circular four months ago, in which it was stated that these bodies " had been giving careful attention to the best means of using our national coal resources. The national importance of the question needs no emphasis, for if coal could be carbonised on a large scale in such a way as to yield a supply of fuel oil for the navy and mercantile marine, and an important share of the motor spirit used in motor cars and aircraft, the balance of foreign trade would be altered in our favour, while the abatement of the smoke nuisance in our towns and manufacturing districts, owing to the abandonment of raw coal as a fuel, would have immediate and far-reaching effects on the health and housing of the people."

We would like to draw your attention particularly to that phrase concerning the *balance of our foreign trade.* It is possible to keep in the country something like £50,000,000 annually which we now send abroad for foreign oils.

Another phrase of great interest in the Mines Department report is as follows :—" The utmost use must be made of the natural resources we possess if we are to recover our prosperity. To-day," adds the report, "it is evident that the technical problems of carbonising coal at low temperatures have been solved in all essentials." The report goes on to emphasise the need of large scale production on a commercial basis.

The Coalite Process.

With your permission we will now give some description of the Coalite process.

As you are doubtless aware, the Coalite process of low temperature carbonisation consists in the heating of coal, without any previous preparation, in closed retorts for about four hours, to a temperature of about 1000 to 1100°F. (say, 550 to 600°C.). The result of this partial carbonisation is to drive off a considerable proportion of the volatile matter of the coal, the valuable products of which are recovered, whilst the residual fuel, Coalite, containing about 8 to 10 per cent. volatile matter is left behind in the fuel. This is the main product.

Thus, as an average, one ton of coal of 25 to 35 per cent. volatile matter subjected in this way to low temperature carbonisation, gives 13 to 14 cwt. of Coalite, together with 16 to 20 gallons of valuable Coalite crude oil, from which motor spirit, lubricating oil and Diesel engine or fuel oil and disinfectants can be separated. Further, it gives about 12 to 15 lbs. of sulphate of ammonia, and 3500 to 6000 cubic feet of very rich gas of 700 B.T.U. value per cubic foot, after stripping of its motor spirit.

The process is quite different from the production of coke in coke ovens, or in gas manufacture, in both of which the coal is heated to a high temperature of about 1800 to 2000°F. In the gas works, the object is simply to get as much gas as possible by conversion of most of the volatile matter in the coal. The consequence is that one ton of average coal carbonised in the gas works gives only about 8 to 9 gallons of coal tar, together with about 25 lbs. of sulphate of ammonia, and 12,000 cubic feet of comparatively low quality town gas of about 450 to 500 B.T.U. per cubic foot, leaving 12 cwt. of soft coke in the retorts, gas being the main product.

In coke ovens (a special high temperature carbonisation process for the production of a very hard metallurgical coke, and in which the gas is only regarded as a by-product) the figures are approximately the same as for gas works.

The Pioneers.

The real pioneers of the modern low temperature carbonisation Coalite process were the late Mr. Thomas Parker, and Mr. F. W. Salisbury-Jones.

The history of the work done by these pioneers in low temperature carbonisation of coal extends from the year 1900 to 1924. It is a story of fortitude and faith in the face of obstacles, natural and artificial ; of opposition, ill-informed and prejudiced. Discouragement and opposition did not daunt the pioneers, and in this year of grace, 1924, the fruit of persistent optimism and courage is being gathered.

The subject of low temperature carbonisation was first mooted in the year 1900. Private research work was carried on by Thomas Parker and F. W. Salisbury-Jones and financed by the latter, up to 1906, when an ideal smokeless fuel was evolved and registered under the name "Coalite."

They came to the conclusion that the only solution of the problem of black smoke was a smokeless fuel, which was to be obtained by distilling from coal the volatile matter which causes the smoke, leaving behind, however, sufficient to give a free burning fuel, which, at the same time, gave great heat and was smokeless.

Various patents were taken out in 1905, serious experimental work having been commenced at Wednesfield, near Wolverhampton. What is generally regarded as Parker's master patent is 14365/1906, in which the whole principle of low temperature carbonisation was explained very clearly.

By this time considerable progress had been made, and the Coalite produced was of excellent quality, but practical difficulties were encountered.

At this time also, foremost amongst the men of science who lent their valuable aid to low temperature carbonisation, were the late Professor Vivian B. Lewes, Professor James Swinburne, F.R.S., Sir William Preece, F.R.S., and Professor H. E. Armstrong, F.R.S. The latter, as early as 1885, had pointed out at the Iron and Steel Institute the somewhat wasteful nature of the gas process.

In the meantime a further considerable number of patents had been taken out, and different types of improved retorts were constructed and experimented with on a large scale.

In 1905 a private limited company (Coalite, Ltd.) was formed by Mr. Salisbury-Jones and financed by him. The original plant at Wednesfield was taken over and enlarged, and other sites were purchased and additional plants erected at Barking, Plymouth and Hythe. Mr. Salisbury-Jones at the same time suggested the erection of two large central low temperature carbonisation plants and super-electric power stations in London, one north of the Thames at Barking, and one south.

The work, however, carried on under great difficulty, was extended to Barugh, in the heart of the Yorkshire coalfields, and it was on this site that the present standardised plant was subsequently erected. Mr. Parker finally retired in 1912, disheartened, having sold his interest, and he died in 1917. Professor Vivian B. Lewes, all along one of the most stalwart champions of low temperature carbonisation, also died in the same year, and alto-

gether at this time the outlook was of the blackest, although Mr. Salisbury-Jones never gave up hope. The new experimental plant at Barugh was hampered in every way during the war through lack of sufficient financial support.

It was with the outbreak of hostilities in 1914, that Mr. Salisbury-Jones and Professor Vivian Lewes sent a report to the War Office advising the Government with regard to the oil position, and asking the authorities for £1,000,000 to provide for the erection of plants to produce large quantities of oil from coal for the navy and mercantile marine. This assistance was not forthcoming, but later in the war the Ministry of Munitions awakened to a sense of the situation, and made a small contribution in the direction of solving the problem. That the peril to this country resulting from our dependency upon foreign oil supplies was recognised with feelings of panic in 1917, is evident from Admiralty reports of that time, and since then constant warnings have appeared in the press.

By 1917 a portion of the plant at Barugh was at last completed, and in the same year the present company, Low Temperature Carbonisation Ltd. (14/16 Cockspur Street, London, S.W.1) increased its capital of £100,000 to £1,200,000 to amalgamate finally all the interests concerned.

Mr. Charles Parker, son of the original inventor of the low temperature carbonisation process, was engaged upon the work with his father, and since 1905 has done most of the practical research work in connection with the process, and has been largely instrumental in bringing this method of treating coal to its present perfection.

The Company has completed the standardisation of units of plant, so that the retorts are about half the cost of high temperature retorts used in carbonisation, and labour is reduced to a low figure.

Further improvements have been devised, and the Coalite is now made in tubular retorts 9 feet long. There are several tubes in one solid casting in each retort. Each battery consists of 32 standard retorts, carbonising 50 tons of coal per day, the retorts being placed side by side in couples; a coal bunker is placed at the end of each battery or series of batteries, and the coal is fed from this bunker into the retorts every four hours. At the end of each four hours, the discharge doors are opened underneath, and the Coalite falls into the cooling chambers, the drop being sufficient to break the fuel into commercial size. In front of the discharge doors a continuous belt is kept in motion for the removal of the Coalite to trucks or to storage.

The Properties of Coalite.

It will not be without interest at this stage to give a short account of the properties of Coalite. The reduction in the volatile content to about 8 to 10 per cent. makes a remarkable difference in the properties as compared with coal and coke, and it is not an exaggeration to state that Coalite unites the advantages of both these fuels.

One of the great advantages of Coalite is that it burns with a very high emission of radiant heat. In the first place, it lights as easily as coal, whereas, because of the almost entire absence of volatile matter in coke, the latter is of practically little use by itself in the domestic fire. Secondly, Coalite shares the advantage with coal in that it burns without smell. Coke nearly always has a tendency to smell of sulphur, although, like Coalite, the actual percentage of sulphur is much less than that of coal. Coalite gives a " cheerful " fire, just like a coal fire at its best. Also, Coalite is made from washed coal, so that the ash content is much less than coal or coke, and, finally, it may be stated that the price is no more than the best coal. At this price Low Temperature Carbonisation Ltd. has sold ahead one million tons of Coalite per annum for four years to one of the largest London coal distributors.

Application to the Colliery Industry.

The Coalite process is of particular interest to the colliery industry, not only from the point of view of the much more economical utilisation of ordinary good grade coal, with a corresponding increase in revenue, but particularly also in connection with the use of low grade and refuse coals.

There are coalfields in Great Britain untouched simply because the coal is so friable, and crumbles so easily that transportation is difficult or impossible. So far as calorific value goes, this fuel is as good as the best hard coal, and is an ideal raw material for low temperature carbonisation purposes. The Kent coalfields and the Forest of Dean deposits are excellent examples. Such properties can be converted into highly successful revenue-producing enterprises. Much of this coal could be raised and treated at pithead at an extremely low cost, in some cases as low as six or seven shillings per ton.

It is an actual fact that small coal is best suited to the process of low temperature carbonisation. It may, therefore, be stated that by low temperature carbonisation of small coal colliery proprietors could increase their revenue by about 30 per cent., and the national wealth of the country be vastly augmented.

One ton of ordinary bituminous coal treated by the Coalite low temperature carbonisation process will produce on an average :—

Motor Spirit	3 gallons.
Oils for Lighting, Lubricating, Disinfectants, etc....	16 gallons.
Smokeless Fuel	14 cwt.
Sulphate of Ammonia ...	12 lbs.
Gas	4000/6000 cubic feet (rich gas) of 750 to 800 B.T.U. before scrubbing.

On a plant capable of carbonising 300 tons of coal per day, therefore, we have an annual output of 1,760,000 gallons of crude oil. From this and from scrubbing the gas 330,000 gallons of motor spirit are obtained There are also about 600 tons of sulphate of ammonia. The yearly output of Coalite smokeless fuel will be approximately 77,000 tons.

By fractionating the crude oil, large quantities of motor spirit, Diesel, lubricating and other oils, are obtained, in addition to the motor spirit recovered by scrubbing the 440 million cubic feet of rich gas made per annum. This is the approximate output of the products from a plant of 200 retorts carbonising some 300 tons of coal per day.

We will now pass to the industrial and commercial aspects. It can be demonstrated that collieries, large and small, would greatly increase their revenue by installing low temperature plants at pithead, and that the low construction costs will enable mine owners to pay for the erection of plants within a very short space of time.

The Times has stated that we have wasted £200,000,000 per annum for many years. This sum equals one-fourth of our debt to America. Since the war, we have squandered wealth representing the whole of that debt. The war was fought largely on economic questions. Germany was beating us in the world markets because her chemists were beating us in the laboratories. She will menace us again if we do not avail ourselves of the discoveries of our own clever engineers and chemists. And, thank Providence, we have still clever engineers and chemists, who, unsubsidised though they are, are proving themselves wiser than the subsidised German article. We have stolen a march on the world, and once again England has taken the lead. We have found means to lengthen the life of our coalfields, and double the value of our principal national asset. We have discovered our Niagara ! Cheap fuel and cheap gas and oil mean cheap production. All is working together for good to them that love progress, as do all here assembled.

The Commercial Aspect.

Here we would refer to the scheme to erect works at Nottingham. A contract has been made with the Nottingham Corporation, who have undertaken to purchase a minimum of 2,000,000 cubic feet per day of standard quality gas for a long term of years. A contract has also been entered into with the Digby Colliery Company to acquire a lease of land for the erection of plant capable of carbonising, by the Parker low temperature process, 1000 tons of coal per day.

A further contract has been entered into with the Digby Colliery Company for all of the coal for a period of twenty-five years. The annual output of the plant will be :—

Gas	1,260,000,000	cubic feet.
Coalite Smokeless Fuel	235,000	tons.
Fuel Oil and Lubricating Oil ...	6,300,000	gallons.
Motor Spirit	900,000	gallons.
Sulphate of Ammonia	2,280	tons.

Large quantities of coal from the Digby Colliery Company have been treated at the low temperature carbonisation works at Barnsley, and, upon the results obtained, it is estimated by the engineers that the profit on the new plant, the capital cost of which will be about £400,000, will be in the neighbourhood of £140,000 annually, after making provision for maintenance, depreciation, administration charges, etc.

Super Power Stations.

Some years ago, a scheme of *super power stations* was recommended by the Directors of Low Temperature Carbonisation Ltd., and at Barking, on the Thames, a beginning was made. The project of erecting a small number of super power stations is one of our most urgent needs, and should be encouraged. There are about 400 individual units at present in this country. Sixteen super power stations could supply all that is required and introduce enormous economies. No country in the world is so favourably situated for the cheap production of power as Great Britain. No important city is more than fifty miles from the seaboard, and dotted throughout the length and breadth of this island are coal mines to feed the industrial centres. Compare these distances with the vast distances in the United States, or, indeed, most European countries. Yet America has been producing cheaper power than we in many parts of those huge territories. But we have now our own Niagara which need never dry up.

The National Significance of Low Temperature Carbonisation.

The advantages of low temperature carbonisation are so enormous from a national point of view that it is difficult to speak on the matter without appearing to exaggerate.

If all the coal used to-day in Great Britain, apart from that for existing high temperature carbonisation processes (gas works and coke ovens), were submitted first to low temperature carbonisation the national saving would be about £200,000,000 per annum.

The whole of the industrial life of Great Britain and the Empire has been built up on coal, and our future prosperity depends upon it.

Taking average figures, with due allowance for wars and strikes, we can say that Great Britain raises 250,000,000 tons of coal per annum, of which 25 per cent., 62,500,000 tons, is sold to the Colonies, foreign countries and ocean-going and coasting steamers, and 75 per cent., 187,500,000 tons, is used at home.

Pulverised Coal and Coalite.

The recent perfection of the process of pulverised coal-burning in the United States, as represented by the "Lopulco" system, using water screens to prevent "slagging" or the fusing of the ash, and hollow air-cooled brickwork, in which the heated air is used for combustion at the burners, is of very great significance.

The important point is that low temperature fuels can be burnt at greater efficiency than coal in the powdered condition, now that all the problems of pulverised fuel in general have been solved.

Powdered Coalite.

Six years ago, in 1918, an extensive investigation was made in the United States into the subject of pulverised coal. At that date several hundred successful installations of pulverised coal equipment, in the iron, steel and metallurgical works, existed. The economical method of firing has been extended to steam boilers, and in some measure to locomotives and for marine uses.

Now, whatever is true of pulverised coal and its value, is true in greater measure of powdered Coalite, the efficiency of which *exceeds* the results obtained by pulverised coal.

There is no question that in England, in the Dominions and in other countries, the reclamation of combustible matter from mine dumps, and the utilisation of smalls, can be developed

commercially by the process of low temperature carbonisation. The treatment by this method of all volatile classes of coal is one of the biggest and most important of our national considerations. We are on the eve of a very great and revolutionary reform in the matter of fuel and power production. If we accept the situation as it stands to-day, our country can again take the lead, as she did at the time of the invention of steam as applied to locomotive and other power. England can once more march ahead of her competitors and gain a lead such as she appears to have lost. It lies in our own hands to inaugurate a new era. We feel confident we shall not fail, either in our own interests or those of our country.

The next most important use of coal is that for households, that is, private houses, hotels, hydros and similar purposes, in open grates. For this we burn 35,000,000 tons per annum in about 8,000,000 separate establishments, with certainly not less than 10,000,000 separate fires in operation. The cheerful open fire is characteristic of Great Britain, and no other nation has such a "fireside." The reason is, that this method of burning coal is so wasteful and extravagant that most other countries cannot afford to waste coal in open grates and have to use closed stoves instead.

By the use of Coalite it will be possible to retain the use of the open fire, still the best method of heating rooms and buildings, and to cut down the domestic fuel bill from 35,000,000 tons of coal per annum to about 20,000,000 tons of Coalite. That is, instead of burning 35,000,000 tons of raw coal we should carbonise about 28,000,000 tons of coal, use the 20,000,000 tons of Coalite for household purposes, save 7,000,000 tons of coal, and recover an enormous quantity of valuable by-products.

The 15,000,000 tons of coal used per annum for steam generation in locomotives is, like stationary land plants, also used in a most inefficient manner, and the use of Coalite would result in a big economy.

All these uses of coal inflict on the long-suffering community the curse of black smoke.

Coalite is completely smokeless because it only contains eight per cent. volatile matter, just as is anthracite (smokeless) coal, containing three to four per cent., and coke, containing about one per cent.

It is amazing that the people of Great Britain go on tolerating this abominable state of affairs. The coal strike of a few years ago gave us a faint idea of the difference the absence of black smoke would make to our private lives. The injury caused by black smoke has been studied in the fullest detail by various

investigators, such as the Municipality of Pittsburg, in the United States, and the Manchester Corporation Committee. The facts are beyond question, namely, that a most conservative estimate of the total cost to the community is £1 per head, that is, about £40,000,000 per annum for Great Britain.

One of the evil results of black smoke is the formation of fogs. One fog of limited duration in a large city causes a loss of hundreds of pounds in extra lighting and transport difficulties, to say nothing of scores of cases of illness, colds, sore throats, etc. It is well-authenticated that the great fog of 1880, in London, caused the death of 3000 people above the average, and over 30,000 cases of illness. Throughout the whole country the deaths and illness due to pulmonary diseases, entirely due to smoke, are an amazing item.

Smoke also causes many other cases of illness and death because the amount of sunlight is seriously diminished, and sunlight is the worst enemy of obnoxious bacteria. Again, smoke causes the most astonishing waste in soap and other material, to say nothing of labour in connection with the extra washing of clothes. In an enquiry instituted by the Manchester Corporation, this point was studied with the greatest care, and showed that out of the total loss of £750,000 per annum to Manchester because of the black smoke, £250,000 was due to extra washing necessary. Other most serious items are the damage done to the stonework of public buildings, the extra painting necessary, and the damage to material in warehouses, etc. Sooty chimneys are another nuisance, and, according to one authority, fires started by smoky and dirty chimneys cost London alone £2,000,000 per annum. The use of Coalite in place of coal will at one blow wipe out most of the black smoke of the country, and save us £40,000,000 per annum.

Home-Produced Oil.

Another point of outstanding importance from the national point of view is the oil question. Great Britain has no oil. The whole British Empire only produces about $2\frac{1}{2}$ per cent. of the oil supply of the world, whilst 65 per cent. of the production is in the United States. British financiers control about 5 per cent. of the world's output, whilst American financiers control about 80 per cent. Thus we import into this country about 250,000,000 gallons of petrol per annum, and because of the high price of petrol the British motor industry is hampered, and the number of cars used per unit of population is much less than that of America. By the low temperature carbonisation of 140,000,000 tons of raw coal per annum, that is, leaving alone the existing high temperature processes and allowing an ample

margin of coal for heating the retorts, there would be produced 300,000,000 gallons of motor spirit per annum; that is, more than the present consumption of the whole country.

Another item of equal national importance is the fact that the low temperature carbonisation of 140,000,000 tons of coal per annum would give about 2,500,000,000 gallons of valuable crude oil, containing Diesel engine and lubricating oil. The Diesel engine, which uses oil direct in the cylinder, is infinitely more efficient than the condensing steam engine and turbine, and will eventually replace them for power generation, not only for stationary land plants, but in marine and locomotive work as well. At the moment, however, we are interested in smoke abatement, so we revert to Coalite smokeless fuel.

To give you an idea of the successful introduction of this domestic fuel, Coalite: during the last year it has been supplied to thousands of customers, and so popular has it become that leading coal merchants in London have entered into a contract to purchase the whole of the output from plants producing up to 3000 tons a day.

To enable the Company to cope with this demand they are now busy extending plant, and are preparing for the immediate erection of new works in other parts of Yorkshire, in Staffordshire, Lancashire, Gloucestershire, and other large coalfields.

We would like to visit Manchester two years hence if in the meantime a large Coalite plant had been erected at, say, half-a-dozen of your neighbouring collieries. Four plants of 1000 tons a day output would give you approximately a million tons of Coalite in twelve months. These plants can be installed in twelve months, so that by the end of a couple of years a vast difference in the condition of your atmosphere, and a great increase in your hours of sunshine would have been effected.

Since the foregoing was written, H.M. Stationery Office have published a report made by the Government Fuel Research Board on the working of a 50-ton per day standardised unit of "Parker" Low Temperature Retorts installed at the Barnsley Works of Low Temperature Carbonisation Limited. The test was made at the suggestion of the Trade Facilities Act Committee to ascertain whether this standard unit would actually carbonise the 50 tons per day it was designed for and, if so, whether the products obtained were equal in quantity and quality to the claims advanced by the patentees and makers.

The full report is now available to the public and can be purchased at any of H.M. Stationery Office Branches, or through any bookseller, at the price of ninepence.

It may, however, be of interest to those present to know the results of the test, and we, therefore, give you the following brief summary :—

1. The throughput of the plant was clearly demonstrated to be equal to that claimed, viz., 50 tons of coal per 24 hours.

2. The products obtained were eminently satisfactory, both in quality and quantity, the yields being on the average somewhat better than those obtained on the experimental plant at H.M. Fuel Research Station with coal from the same colliery and seam.

3. Certain suggestions as to improvement in details of the plant tending towards additional economy in working were made by the Fuel Research Board, which are being incorporated in the plant to try them out in practice, and if found advantageous will become standardised in future plants. These suggestions the Low Temperature Carbonisation Limited gratefully acknowledge.

The coal used in the test was Dalton Main Washed Singles ; a fuel which has been frequently tested in every way at the Fuel Research Station.

The yield of products per ton of coal carbonised was as follows :—

"Coalite"	13·92 cwts.
Gas	5620 cu. ft. or 39·6 therms after stripping of spirit.
"Coalite" crude oil	18·62 gallons.
Ammonia Liquor	26·00 gallons.
Crude Motor Spirit from scrubbing the gas	1·78 gallons.
Equivalent ammonium sulphate ...	13·55 lbs.

The Coalite produced was of a very suitable size (1 to 3-inch pieces) containing only 4·6 per cent. of breeze, and was quite suitable to withstand the rough handling natural to rail or road transport. Analysis of this fuel showed a slightly lower percentage of volatile matter than usual, but when burnt in a household grate it readily ignited and gave a good hot fire.

The yield of crude oil was high, showing 68 per cent. of that obtained in the standard assay apparatus developed by the Fuel Research Board, and upon examination proved to be a normal low temperature coal oil.

The yield of gas was greater than that anticipated from this particular coal, and averaged 705 B.T.U. per cubic foot after being stripped of its crude motor spirit.

The motor spirit obtained by scrubbing the gas was 1·78 gallons per ton, but as the crude oil also contained 1·09 gallons the total yield of this product amounted to 2·87 gallons per ton; a most satisfactory result.

The ammonia was also higher than expected, and when converted into ammonium sulphate yielded 13·55 lbs.

From the foregoing summary it will be seen that the claims made for the "Parker" system of Low Temperature Carbonisation have been finally demonstrated by the Government Fuel Research Board through their technical experts, of acknowledged capacity and reputation. It only remains, therefore, to put into being a whole series of really large scale working plants of similar type, scattered throughout our colliery districts, to realise in full the benefits to the community to which we have drawn attention in this paper.

As Sir William Kay had to leave, the Chair was taken by the Chairman of the League, Mr. J. W. Graham.

Dr. C. H. Lander (Director of Fuel Research under the Department of Scientific and Industrial Research) said they had heard that afternoon the views on low temperature distillation of three of the groups who were attempting to find a commercial solution of the problem of smoke pollution on certain well-defined lines. They had seen, he thought, that a technical attack might be made on this problem in two distinct ways, one by externally heating the retort, which was the method adopted by the Coalite people, and the other, which was adopted by Mr. Maclaurin and Mr. Nielsen, by heating the retort from the interior. These two methods were to a great extent complementary one to the other, and he thought he would be forgiven if he said that each had certain disadvantages, and most certainly each had advantages. There was an alternative method of trying to utilise both methods of heating at the same time, with the usual result of combining the disadvantages of both with the advantages of neither.

However, he did not propose to enter into a discussion of the technical aspects of the problem. He wished to draw the attention of the Conference to the views held by the Department which he had the honour of serving, as to the national aspect of the matter. He must differentiate between the national aspect, which had

reference to the complete conversion of very large quantities of coal, and the local aspect, which related to the solution of some important problems as to the utilisation of slack and coals not at present marketable. It was a very important direction, and would undoubtedly come first. But he wanted to make it clear that in what he was about to say he was simply referring to the national side of the question, the question how far they were from making the navy totally independent of foreign oil by the substitution of low temperature carbonisation fuel, or some other fuel, for coal in the domestic grate.

He did not want to confine his remarks to low temperature carbonisation fuel. Reference had been made in one of the papers read to a statement recently issued by the Mines Department and the Department of Scientific and Industrial Research. After quoting the views of those two great Departments, the paper went on to emphasise the need for large scale production on a commercial basis. In that connection he wanted to strike a note of warning from the point of view of the national aspect ; he wanted to state what the view actually was that was taken by those two Departments. For that purpose he was going to use statements that were actually published and to which anyone may refer, so he was not giving away any secrets in this matter. The view taken was that no one can say definitely whether commercial success is possible ; this can only be demonstrated when a plant of sufficient size has been in operation for some years, so that the problem can be reduced to one of mere commercial audit. If, after steadily working for some time in this way, any of the groups interested can demonstrate their success in this practical manner, then the time will be ripe for " large scale production on a commercial scale," and he had no doubt whatever that the industries interested would take the matter up with vigour.

That was perhaps only reinforcing the remarks that had been made at the Conference and also at the Exhibition. Reference had also been made to a report of a test on a " Parker " plant which had been recently issued. This was the report Mr. Roberts mentioned. He was sure Mr. Roberts would forgive him if he

emphasised the necessity for really recognising what that report said. It was a technical report confirming the claims made by the Company as to the production of their fuel, of oil, gas, ammonia and so on; it said that those claims were substantiated, that the process actually produced the goods. But there was a qualifying prefatory note from which he would like to read an extract :—

> " The object of these tests is to place in the hands of those interested accurate technical data on the quantity and quality of yields, the throughput of the plant, the working temperatures and the general ease of working, together with such other information as it may be possible to obtain under the limited conditions of the tests. It should be clearly understood that no attempt is made to pronounce on the commercial possibilities of plants which may be tested. The likelihood of commercial success can only finally be judged after working a plant under a steady load for a long period, and in the light of complete knowledge of local conditions such as cost of raw material available, price and markets for products, cost of labour, etc.
>
> " In other words, the report places in the hands of industrialists or others who may possibly be considering the erection of low temperature plant, accurate technical data from which they can, in the light of their own local circumstances, make *their own* prophecies as to the likelihood of commercial success."

Nobody else could do that but the man who knew exactly what he could get the coal for, how long he could get the coal at that price, what he was likely to get for the products, and so on. Such considerations involve many important factors, such as the present prices of raw material and products and the trend of future prices. It must not be forgotten that large developments in this direction will in themselves affect such prices.

It was important not to lose sight of the considerable benefits and indirect savings which would follow the use of smokeless fuel or gas on an adequate scale, but taking such savings into consideration could only be brought about by parliamentary action of some kind, and when the innate conservatism of the British public was taken into consideration it would be admitted that such action would only follow the education of the British public in the manifest advantages offered by development in the

use of such fuels. The labours of organisations such as the one to which this Conference was due, could not be over-estimated, since the alleviation of the smoke nuisance could only be achieved by the enlightenment of the consumer in the direction of his best interests.

He would like to read a portion of the annual Report of the Committee of Privy Council for Scientific and Industrial Research. This was issued in August last :—

> " Low temperature carbonisation of coal is attractive, since it produces both smokeless solid fuel useful for domestic and industrial purposes, and a supply of motor spirit and of liquid fuel needed for the navy and mercantile marine. It would not be a specific for all our troubles even if it could profitably be adopted for the forty million tons of coal annually used in domestic fireplaces. Owing to the variation in the coals available and in the local conditions, a number of different processes will possibly have to be devised before success on a national scale is achieved. It is quite certain that no single process has yet become established which would be suitable for application on a national scale. Before it would be feasible to prohibit the use of raw coal in our houses, it is therefore necessary to find a process and a type of plant, or a number of processes and types of plants, which collectively would pay their way when the raw coal is purchased at approximately the same price as coal now sold for household or other general purposes."

That was all he had to say. It was gratifying to find that low temperature carbonisation was getting into such an advanced state of development that they could say unhesitatingly that there were certain plants which would produce the goods, which would produce the coke, oil, gas and other products. Certain plants were in existence which would do that. What nobody knew yet was whether they were going to get twenty-one shillings for every pound that was expended or whether they were going to get nineteen shillings. On many occasions he had tried to draw up balance sheets of the processes, and he had got all kinds of funny results, varying from eight shillings a ton loss to eight shillings a ton profit. That was really the position they were in at the present time. They certainly hoped that development would be very rapid in this or in any other direction which would

tend to solve this national problem, and at the same time make us independent or partially independent of foreign supplies of oil fuels.

Mr. E. Kilburn Scott said he wished to ask Mr. Maclaurin whether in his plant for making low temperature coke it was necessary to mix the coking coal with non-coking coal. In the Parker process mentioned by Messrs. Roberts and Pope he believed they had to mix the two kinds, because if only coking coal was used it was liable to stick in the retorts, and if it was non-coking, then the semi-coke product was too friable.

Would Mr. Maclaurin also give them some information about the minimum percentage of volatiles that was necessary in a smokeless fuel. The general impression was that a smokeless fuel must contain eight to ten per cent. of volatiles, in order to make it burn cheerfully in an ordinary household grate. Apparently, however, the question of whether a smokeless fuel would burn well or ill did not depend so much on the percentage of volatiles contained as on the character of the coal from which it was made, and on the porosity of the resultant semi-coke.

In one of the low temperature carbonisation processes shown at the Exhibition, coal was pulverised and then briquetted under great pressure before being treated in low temperature retorts. The resultant semi-coke was said to burn well in an open grate with only two per cent. of volatiles. Apparently, some kinds of semi-coke having only three to five per cent. of volatiles would burn with a cheerful open fire if they were made from the right mixture of coal and by a suitable process of carbonising.

He knew the late Thomas Parker personally, having been associated with him in the same electrical company about thirty years ago, and knowing also something of the early troubles that low temperature carbonisation had had to contend with, he thought the way the early workers had hung on, and made the Parker process a commercial success, was very commendable.

But, of course, other methods were coming along; for example, there was one at the Walkerville Works of Ford Motor

Co. Limited, Canada, invented by a British subject and first tried in England ; also another, the invention of a Scotsman resident in London, and now being tried out in Milwaukee.

A special point about these two processes which differentiated them from those mentioned in the papers read that afternoon, and from most of the fifty methods that had been patented, was that the coal was in a small state of sub-division, and the gases could get away freely without passing through either raw fuel or incandescent fuel.

In the Maclaurin plant, and also in the Parker retorts at Barnsley, the gases given off had to pass through other fuel, and in doing so they were altered in character, and oils were cracked.

In the Piron lead bath process used at the Ford Motor Works at Walkerville there was a long muffle furnace with a molten lead bath in it, and on the lead a number of trays moved continually along like the trays in an oven for baking biscuits.

They entered the muffle at one end and soft coal in a small state of division was dribbled on as a thin layer, and the trays then moved through the muffle at such a speed that the temperature of the melted lead was just right for producing a semi-coke containing ten or twelve per cent. of volatiles. The coke dropped off the trays at the delivery end and was pulverised, so that ninety per cent. would pass through a 100-mesh sieve, and it was finally burnt as a mechanical gas in power station boilers.

The gases and oils passed off quite freely, without having to go through any other incandescent fuel, and the bye-products were recovered in the usual way common to gas works and coke oven plants.

The plant at Walkerville was treating 400 tons a day, and another plant designed by S. V. Caracristi was now being erected at the Ford Motor Works at Detroit to treat 1400 tons a day.

The other process he had referred to as being tried at Milwaukee seemed to have a future, because it fitted in with the great progress that had been made in the use of pulverised fuel for firing power station boilers.

The coal was first pulverised finely and then dribbled down a long tower in which it met an ascending current of hot air, or of gases. Owing to the fuel being in a fine state of division, each particle was immediately acted upon by the heat and the gases distilled off at once. So that by the time the fuel fell out at the bottom it was of a smokeless character with just the right amount of volatiles, and it was in the fine state of division required for pulverised fuel firing. The gases had not to pass through any other fuel, the oils did not get cracked, and at the same time the whole plant was under exact control.

The trouble with most other processes which treated the coal in lumps was that the outer layer was liable to be over coked before the centre was fully acted upon.

Gas works coke had a grey outer layer which was fully coked and therefore did not ignite, whilst the core was dark or black with volatiles still in it.

In the Maclaurin process the fuel was apparently treated right through, but this was done by carrying out the process very slowly. In the Parker process the fuel had to be in retorts of relatively small size in order to get the heat through to the centre of the mass.

Clearly the ideal way was to have the raw coal in a small state of division so that the gases could be distilled off quickly.

Mr. Maclaurin said the first question Mr. Kilburn Scott asked was about coking and non-coking coals.

In the Maclaurin plant they did not mix the coals ; they took the coal as it came from the mine, and so long as it had a coking index under 16 there was no trouble. They had put through coal in large pieces with a 24 coking index without trouble, but could not treat this class of coal when much small was present.

The percentage of volatile matter left in the coke was interesting. Their experience was that an easily ignited smokeless fuel was obtained when the volatile matter was between three and four per cent., and a non-reactive grey coke quite unsuited for the

domestic grate was obtained with the same percentage of volatile matter. He had samples with him of inactive silvery grey coke with over four per cent. of volatile matter, and of reactive smokeless fuel with only three per cent.

The subject was worthy of scientific investigation. He had tried to show the difference between reactive and non-reactive coke on the screen, but it could be more clearly discerned in the samples he had with him.

He was glad to learn that Scotsmen were settling the smoke problem all over the world.

The next point that was raised was whether the oils were being destroyed by passing through hot fuel and coming in contact with the sides of the retort. In the Maclaurin plant the gases as they were given off, containing the oils, were always passing into regions where the temperature was lower than in the region at which they were evolved.

He thought that the ammoniacal liquor contained proof that almost no decomposition was taking place in the oils after they had once left the coal. In the liquor given off under low temperature conditions were a large number of polyhydric phenols. These phenols could not exist if they had passed through high temperatures or touched red hot coke. Ordinary gas works liquor contained both ferrocyanides and sulphocyanides. It was in fact a horrible mess.

Mr. Maclaurin then showed samples of wool dyed directly by boiling in the low temperature liquor to a slatey blue shade. The colour was due to the presence of iron and a polyhydric phenol. A sample of wool dyed green by a dye extracted from the ammoniacal liquor was also exhibited. The presence of these was proof that little decomposition had taken place.

Mr. Evan Roberts, Junr. (Chairman of the Manchester and Salford Sanitary Association), said they had heard on the previous day that domestic fires were responsible for much of the effects mentioned. The late Chairman of the Association,

Mr. Wm. Thompson, F.R.S.E., F.C.S., F.I.C., the eminent chemist, whom the audience would remember, and the great amount of work he did for many years in regard to smoke abatement, after many experiments with the then known low temperature fuels on the market, recommended coalite as the best fuel for domestic fires.

Upon being appointed chairman, in the place of the late Mr. Thompson, he (Mr. Roberts) continued to recommend coalite, but wanted to state his difficulty. When one came before the public to recommend an article it was advisable personally to know something about it, therefore the Hon. Secretary, Mr. Wilson, and himself sent for a quantity of coalite, and both tested it as well as they could in houses and offices, and Mr. Wilson tested it in the heating apparatus in his church and home, but they were not experts.

They found that the carriage cost them more than the coal delivered in offices. Therefore, he could not go to the public and recommend it from an economic point of view, but for the reason to have a better atmosphere in the cities.

He was sorry Sir William Kay had gone. The late Chairman of the Association approached the Gas Committee three or four years ago, for it was decided by the Association that if they could get the corporations in the large cities to select the best low temperature carbonisation plant and erect a small plant in their gas works, and produce low temperature fuel for sale to those who were willing to pay the larger expense (if any) in order to have a clearer atmosphere, they would be going a long way towards solving the problem of smoke abatement. If the companies marketing low temperature fuels, etc., at this Exhibition would get out the difference in cost between coal and their fuels, and the heating properties of both, they would be doing a great service. That was a question he was very often asked. If they had got that information, he would like to know it.

Mr. Laskey (Chief Sanitary Inspector at Eccles) said he would not have taken part in this discussion if it had not been for the

very interesting paper of Mr. Roberts, and the inquiries made by the preceding speaker. For two years past in the Public Health Offices of the Borough of Eccles they had been using coalite for their own fires, in order to demonstrate to the public that there was a smokeless fuel which was obtainable, and, if their own experience was anything to go by, was obtainable at a fair cost, not in excess of the price of coal, which gave off heat quite equivalent to that of coal, and in giving off such heat gave off no smoke. For two winters past they had been using this, and in order to encourage the use of coalite and demonstrate to the public that there was such a fuel on the market, they had thrown their offices open to anybody who cared to come in and see the fires actually in use. He had no hesitation in saying that, as the result of their experience, they would continue to use coalite so long as they could get it at anything like the present prices. He believed their last supply came from Barnsley, and they paid 56s. per ton delivered into the siding, from which they had to cart it to their offices. They were getting it at a cheaper rate than a good first-class house coal.

He was not interested in the Low Temperature Carbonisation Company, he had no shares in it ; his only object in rising was to say that there was a fuel which in his opinion was infinitely superior to coal, and a great deal superior to gas. It could be used in any domestic grate, but they found it was most successful in those grates which were constructed on the well-fire principle where the air was supplied at the bottom of the grate.

Now this would meet the difficulty of their friend the Medical Officer of Health for Salford, who appeared to think it would be difficult to persuade the British public to give up the use of open fireplaces. Here was a fuel which could be used. They had had no difficulty in obtaining supplies. They had sent their orders direct to the Low Temperature Carbonisation Company. They had not been in direct communication with the people who produced the coalite, but the orders were passed on somewhere, and they got their supplies with very little difficulty. When their present supply ran short they would not hesitate to send on

further orders, and as long as the supply was available they would continue to use it.

The following letter received from Mr. SYDNEY H. NORTH (London) was read :—

I have been surprised at the prejudice that prevails in many quarters against the low temperature treatment of coal, a process which, if put into practice, is going to do this country greater good than any movement of recent years. Coal is the most important national asset we possess, and its continued use in its raw state is driving the country into a very difficult if not dangerous position. By its rational treatment, that is, by extracting from it those constituents which are not essential to it as a heat producer, by the proper treatment of the millions of tons of coal now wasted, either by being left in the mine because it is under present conditions unfit to be marketed, or fine and dust at the surface, from screening, etc., we should be enabled to supply cheap high-grade smokeless fuel, the indispensable condition for producing cheap commodities.

It is evident that there are influences working against the adoption of this low temperature treatment. Government committees have frequently advocated the departure ; members of Parliament have spoken in its favour ; the Expert Committee appointed during the war recommended it ; and the late Minister of Mines had in hand a detailed report stating what could be achieved in different districts in the distillation of cannel coal ; yet no progress is made from a national point of view. It is difficult to ascertain the reason of this deadlock between approval and practice, seeing that a number of the existing processes are capable of attaining at least from 60 to 70 per cent. efficiency.

A month or two ago a Committee appointed by the Ministry of Public Works of France proposed that, in order to introduce a policy of treating raw coal for its by-products, a small tax should be placed on all raw coal, and that this tax should form a fund for assisting in developing the new industry. Would such a committee dare make so revolutionary a suggestion,

unless it was confident that low temperature treatment would realise, technically and commercially, the desired ends ? In the face of these facts, one must come to the conclusion that it is not the inefficiency of the new method proposed, which is standing in the path of progress, but strong interests which would be affected by the general adoption of low temperature treatment.

There is another point. Do the detractors of the system which alone can enable us to build up our own oil supply realise what significant strides oil is making in shipping alone ? In 1914, of the total tonnage of ships constructed, 88·84 per cent. were fired by coal ; in 1923, or ten years later, this proportion had declined to 68·87 per cent., or an increase in oil-driven vessels of 20 per cent. The motor ships in 1914 represented ·45 per cent. of the ships constructed, and in 1923 this figure had advanced to 2·56 per cent. This is sufficient evidence of how rapidly oil is moving as a fuel and a rival of coal ; it also indicates that as the years go on more and more coal will be displaced. Is not this argument emphatic enough to compel us to set about establishing a home oil supply, and not only to silence those who condemn low temperature distillation of coal, but to induce every opportunity being given to those who have expended time and money on perfecting the processes introduced, to prove that it can be effected without the possibility of failure ? This is far too vital a matter to be balked by prejudice. It is one of the most pressing national problems and must be tackled in a broad, statesmanlike manner, or the writing is on the wall for industrial Britain.

A vote of thanks to the readers of the papers, was carried by acclamation.

Fifth Session of the Conference

WEDNESDAY, NOVEMBER 5th, 1924

CHAIRMAN: DR. H. A. DES VŒUX.

THE EFFECT OF LIGHT ON HEALTH.

The CHAIRMAN, in opening the Session, said he might make a remark which he had often made before, and which was still true, he thought, that in this question the ladies took less interest than the gentlemen. He had always felt that it was one of those things that ladies ought to take up, indeed they ought to take more interest in it than men, because it affected them quite as closely if not more closely than it did men ; but for some reason although women asserted they were in the fore-front in all the attacks upon the evils which afflict us at the present day, they had not become sufficiently interested in this great question. He wished those gentlemen who had influence with their wives would try to interest them a little in it. He himself had tried to do so for many years, and he was an utter failure. Many of his friends had tried, but they also were failures. But then they came from the south ; perhaps the northerners still had some power over the female elements in their families.

The following papers were then read :—

The Effect of Light on Health

by MR. LEONARD HILL, M.B., F.R.S.,

Director of the Department of Applied Physiology at the National Institute of Medical Research.

The exposure of the naked body to open air and sunshine, as practised by the ancient Greeks and Romans, has a most beneficial effect on health. The athletes from whom the great Greek sculptors modelled their statues sported naked in the sun

and air. The curative effect of open air and sunshine has been shown in children crippled by tuberculosis of the spine or joints, and in rickety or weakly children. Children with diseased spines or joints are splinted and put at rest, and then exposed naked to the open air and sunshine, whenever the weather allows. They quickly become hardened, and stand exposure just as well as the naked savages who inhabit the cold, bleak, damp country near Cape Horn. Their appetites become good, their muscles hard, and their dispositions happy ; and given plenty of good food, they with time become cured of their troubles, and grow up into strong and healthy citizens. The rickety children owe their diseased bones to want of sunlight and fresh air, over-clothed and confined as they are in tenement dwellings, just as much as to a badly chosen diet. Given plenty of exposure to sun and air, they become cured of their rickety bones, even though their diet remains an ill-chosen one. Children kept in a ward under glass do not get so cured, because the glass filters off the healing rays. Animals such as young chickens similarly may grow up strong and big on an ill-chosen diet, if given plenty of open air and sun, while those kept in dark houses on such a diet remain small and weakly, or die off.

For successful open-air treatment, the cooling effect of the air must be given play, and the sun be not too hot. The open air, by cooling the skin, tones up the muscles and nerves, and increasing the heat production of the body deepens the breathing and increases the appetite, and makes healthy the organs of digestion. While the breathing of cool air acts on the nose, throat, and lungs in such a way as to enhance their protective mechanism, and keep off catarrhal infection, the sunshine acts on the skin. While the dark heat rays mostly warm the surface of the skin, the visible rays penetrate to, and locally warm, the blood.

It is, however, the ultra-violet rays which act most powerfully on the skin, exciting changes in the deeper cells of the epidermis by which they are absorbed. The ultra-violet rays of the sun are those which lie beyond the violet end of the spectrum, invisible, but having great power to produce chemical changes, as instanced by their action on a photographic plate. Clothes, glass, mist, and smoke cut off the ultra-violet rays. Much has been made of the sterilizing effect of these rays, but having very small power of penetration through the living substance they act only on the surface film which absorbs them. Thus they sterilize the surface layer of a culture of microbes, but not the layer beneath the surface. One microbe is able to shade another from the shorter ultra-violet rays, so small is their penetration. (J. E. Barnard.)

The ultra-violet rays are classified into inner, middle, and outer. The inner, longer ultra-violet rays penetrate the skin,

together with the visible rays of the spectrum, and are absorbed by, and warm, the blood in the skin. The outer, very short ultra-violet rays cannot penetrate the horny layers of the outer skin, and so are without action. The middle rays penetrate to, and are absorbed by, the living cells of the outer skin, and produce a reaction which results in flushing of the skin and a greater power of the blood to destroy microbes, signifying a rise in the general resistance to disease. Peeling of the skin and pigmentation follow later. Over-exposure to these rays results in sunburn, with redness, soreness, and actual blistering. A person may be made ill, and the power of the blood to destroy microbes be lowered, by over-exposure.

The growth of all vegetable life is due to the sun's rays, and the sun endows young green vegetables with principles necessary for us. There are in all young green food, and in the milk of cows and eggs of fowls fed on young green food, subtle active principles called vitamins, which are necessary for reproduction of the race, growth, and health. Exposure of a cow to sunlight increases the amount of the growth of vitamin in her milk. While stall-fed winter cows have very little, meadow-fed cows have much of it. We want to eat raw salads and young green vegetables lightly cooked, not spoiled by prolonged boiling, and to drink milk and eat butter of meadow-fed cows.

Now smoke pollution of our cities not only robs us of most of the ultra-violet rays which should stimulate the skin and keep us strong and healthy, but also prevents the growth of salads in city courts, roofs and window boxes, and diminishes the growth of green vegetables and grass for cows in the suburban gardens and fields. The value of cows falls off round Manchester and surrounding cities, owing to the want of green meadow grass. Smoke pollution enhances the cost of milk, and makes its value in vitamin less. Smoke pollution, also, by making the surroundings so dark, ugly, and dirty, drives people indoors, and away from healthy open-air exercise in the hours of leisure. Moreover, the acid fumes of a smoke fog have an irritative effect on bronchitic and asthmatic people.

It has been shown that when smoke fog and white frost go together, the death rate in the big cities is notably increased. The respiratory disease death rate for Salford has been 3092, against 1867 for England and Wales. Smoke pollution increases the labour of people in washing, cleaning, etc., and by increasing the obstruction to transit which arises from mist, delays, fatigues, and irritates people. In all these ways it impoverishes health. In Southport 176 tons of soot per square mile fell down in the year, against 314 tons in London, 794 in Rochdale, and 885 tons in Newcastle. The soot cuts off the ultra-violet rays even more

than it darkens the light. We have contrived a simple method of measuring the ultra-violet radiation each day, and the results are published in " The Times " weather report. They show that the smoky City of London receives one-half to one-third, or less, of the ultra-violet rays which a clean country place receives 30 miles away. The loss of the ultra-violet rays is colossal. The method to which I have just referred, and which is being adopted at many stations, enables us to get a measure of this loss, and will permit us to wield a powerful weapon for getting rid of pollution by smoke.

At present we use coal most uneconomically, wasting the greater part of its value and polluting the sky, making gloomy our surroundings, impoverishing our health, and giving ourselves any amount of needless work. New York and the Ruhr district of Germany have reformed and become purified. So must our cities. Let Lancashire lead the way. By distillation of soft coal we get smokeless fuel, such as coke for raising steam or electric power, and for heating purposes in domestic fires, stoves, and boilers ; also gas for power, lighting, heating, and cooking. And there is the tar, with its hundred uses, including road-making, the provision of motor fuel, and of many valuable dyestuffs and chemicals. Lastly, in place of polluting the air with sulphur acids and killing plants, we get an immense supply of ammonium sulphate, a most valuable fertilizer for raising crops.

Electric heaters are clean, easy to use, and free from fumes, but unfortunately to turn the heat of coal into electricity and electricity back into heat is the most wasteful way of using coal —nine-tenths of the energy of the coal being wasted. To ensure the full economic and cheap use of coal, we must distil it ; and one of the chief products is gas, which must be utilized. Now, coal gas is a most valuable source of heat for fires and cooking ranges—a smokeless fuel easy and clean to use, and giving us in open gas fires visible rays which penetrate to the blood beneath the outer skin, and warm that. Dark heat from hot water and steam coils warms more the outer surface of the skin, and penetrates less to the blood. Warmed by the rays of an open fire, we can bear an open window in comfort ; while with sources of dark heat this is not the case, for the open window lets the hot air escape on which we largely depend for warmth. Thus, using dark heat we come to live in a stagnant, stuffy, warm air, which is bad for health and a great cause of catarrh.

Danger arising from the poisonous nature of gas has been magnified both by some who strive to be just and by others who have interests opposed to the use of gas. The poisonous nature of gas requires that it should have given it a smell by which leaks are detected and people warned that fittings should be

good, and that persons should be taught the danger of leaks and fumes from gas rings and cooking stoves and properly to ventilate their houses. Good ventilation by open window has a most beneficial effect on health. Carbon monoxide, the poisonous substance in gas, combines with the red colouring matter of the blood, displacing some of the oxygen which is carried by the red blood from the lungs to the tissues. It has no other poisonous property besides that of robbing the blood of oxygen. How much it robs the blood of oxygen depends on the percentage of carbon monoxide in the air which is breathed in, and how long it is breathed. It takes a considerable time for carbon monoxide to get into the blood, and to get out again when fresh air is breathed. If the percentage is very low, as in the case with the slight leaks from gas pipes or fumes from the appliances when gas is not wholly consumed, the small amount of oxygen displaced by it from the blood is negligible, and does us no harm; for we always, when at rest, have more than enough oxygen in our blood—the surplus being kept ready for any sudden exertion. We know that the health of the employees of gas-works, who are frequently breathing small amounts of gas, is not impaired; and the natural ventilation set up through chinks and crannies by differences in temperature within and without a room is, except in warm weather, so great that, even though windows and doors are closed, small leaks of gas do not make the air poisonous or unhealthy.

A very small percentage of carbon monoxide may escape being burned in gas fires, rings, and stoves; and all fires and stoves ought to be flued. We have found, however, by recent experiments, that even three flueless gas stoves burning in one small room on a cool day, with door and window shut, did not raise the percentage of carbon monoxide in the blood to an appreciable degree. The hot air and sulphur acids arising from such stoves, however, made the head feel stuffy, through causing the membrane of the nose to become congested and swollen. Ample ventilation by open windows should be provided with all stoves, whether gas, coke, or anthracite.

By attention to fittings and education of the public, gas can be safely used, and experience shows that it has been so used for scores of years. The fatalities due to gas poisoning in one year were 2 per million, against 22 from railway accidents, and 100 from street accidents in London. In 1919 there were 992 inquests held on children burned by accidents with open fires. I have said this about gas, because constantly quite erroneous statements are made regarding carbon monoxide poisoning from gas, and the public must understand the truth of the matter.

The next great health reform is the proper use of coal, the purification of air from smoke, and the setting-up of the habit of taking baths in the open air and sunshine in the summer, and using arc light baths in the winter.

The Effect of Light on Health

by Dr. R. Veitch Clark, M.A., M.B., Ch.B., D.P.H.,
Medical Officer of Health for Manchester.

I feel myself rather in a difficulty on an occasion like this, because I am preceded by one who is probably the greatest authority on this subject in the country, and who has dealt with practically every aspect of the effect which light has upon the wellbeing of man. But there are certain ways, I think, in which we might look at this subject, and which, perhaps, appeal to me a little more than they may appeal to Professor Hill, owing to the nature of our respective spheres of work, and these, I think, I would like to mention.

First of all, it seems to me extraordinary that at this time of day we should be discussing as an educational procedure—for that is why we are met in conference ; we are creating a public opinion—the effect of light upon health. Why do I say that ? Primarily, because most of the advancement in ordinary life is a matter of human experience. Scientific investigation very frequently opens up entirely new worlds to us, but in matters of this sort scientific work is only explaining the reasons underlying those facts which, if we only use our intelligence, are already known to us. Why is it that, whenever we get a chance, we flee from Manchester, from Sheffield, from Birmingham, or any other large industrial centre ? It is because the atmosphere is inimical to our best interests. Why is it that when we think of taking a holiday we choose a place where there is bright sunshine ? It is because we do not get it at home, and our bodies miss it, and because it is borne into mankind, as a result of experience, that it is the sunlight we are missing and that it is the sunlight we need. We all know that ; everyone of us. Ask the man in the street what he is going to do on his holidays. He will say, " I am going to the seashore." " Why ? " " I want some fresh air and sunshine." I am not speaking specially of Manchester ; I am speaking of any of our industrial centres when I say that we are doing practically nothing compared with what could be done to produce the conditions in which we know we ought to live.

I think if anything were needed to prove the crass stupidity of man it is the need of a meeting like this. That is the first point that I wanted to make.

The second point, and it is, perhaps, a less general one, is nevertheless quite as striking. It is over twenty years since sunlight really began to be used for the cure of disease, and more especially is that true of the most famous of all sunlight cures, that which is carried out by Dr. Rollier, at Leysin, in Switzerland I will have something to say about that soon, because I had the good fortune to be at Leysin last August, and actually saw Dr. Rollier's work in progress.

I want to direct the attention of this gathering to the fact that for twenty years it has been well known to at least a section of the medical world, and it has been known to practically all the medical world for the latter portion of that twenty years, that sunlight is a necessary means of treatment of diseases. We should really use the term " solar radiations," because it is not really light, but the rays outside the visible spectrum. But the word " sunlight " is sufficient to convey my meaning. Knowing, as we do, that it cures disease, we take no precautions to make sure that it induces health. That is the first basal, fundamental standpoint ; that we must make it our specific endeavour to inculcate into the public mind the fact that light is really health.

I would like to say a little about one of the points which Professor Hill stressed respecting the biological support that exists in favour of the effective and useful influence which light has upon our wellbeing. All of us know that chlorophyll is the green colouring matter of plants, and I would like just to mention, in passing, that chlorophyll is practically inactive except in the presence of sunlight. It is the pigment which enables the breathing of plants to be carried on. Not only that, the sunlight is the agent which is essential to the plant for the storing up of the plant foods, carbohydrates and proteins. The synthetising of these substances, the construction or the making of these substances in the plant, depends directly upon the influence of sunlight.

I am sure that Professor Hill would, if he were speaking, support me in this, that there is no break in continuity in the organic world. Vegetable life and animal life, right up to man, who is at the apex of the animal tree, is a continuous world, and if we find that in such conditions as those affecting the vegetable world that sunlight is absolutely fundamentally the thing which is necessary for the normal life of the plant, even *a priori* it must be equally true that sunlight is essential to our personal welfare.

There is still another point I want to make. Where is it that the light hits us ? Suppose that we were in that delightful state which Professor Leonard Hill described to us, or imitated, perhaps, the ancient Greek athletes, or, perhaps even better,

that we are enjoying a swim on our annual summer holiday, what is it that the sun hits ? It is our skin and our eyes.

Let me take you, very superficially, into embryology for a moment. The outermost layer of the embryo which is eventually to develop into the human being gives rise, amongst other things, to the skin and to the nervous system, the brain and the spinal cord. The main portions of the eye—not all of it—are formed from the skin and from the brain. So that the eye and the skin and the central nervous system have, embryologically, all the same origin.

Let me direct your attention to three points. The eye is the organ that responds to the section of the spectrum which we call the visible spectrum. It is the organ which changes the light-waves into sensation ; what we know as the sensation of light. The skin receiving the rays of the solar radiation responds, as we have been hearing, to the ultra-violet rays particularly. There is quite a narrow band of those ultra-violet rays which is responsible, among other things, for example, for the pigmentation or browning of the skin. Further than that—to take a third section, the brain and spinal cord—there is a condition known as heat stroke. That condition has been the subject of much discussion as to its actual origin, but, personally, I am pretty thoroughly convinced that when our knowledge of the action of the non-visible part of the spectrum is elaborated more, and there is a great deal more to be done, we shall find that the intense collapse, the high temperature and the severe illness, is really attributable to an overdose of the radiation activity of the ultra-violet rays.

Thus you have three systems in the human frame, two of which we know definitely, and one which, I think, will be shown to be directly affected by solar radiations. Professor Hill has referred to the changes in the cells of the skin. It is highly probable that similarity in the embryological origin of these three systems will be found to have its parallel in the action of sunlight upon our physical systems.

I might elaborate this somewhat further, but I think I will proceed to my next point, the psychological effect of light. Nobody can tell at present what is the basis of psychological action. We do not know what it is that underlies our emotions, and the emotions are the things which determine our action in at least ninety per cent. of our lives. There is very little reason in the human being. The greatest proportion of our actions is based upon emotion, and there is little doubt that we shall be able to elucidate physical, or rather I should say physiological, causes for a considerable proportion of the ordinary animal emotions—pleasurable emotions, painful emotions and so forth. I am not

going to dwell too long on this because psychology always tends to get rather " gaseous," but I do want to remind you that it is a very important factor in the life of the ordinary man and woman. What is it that we find in ordinary phraseology, in the language of our mothers ? We find that whenever there is anything pleasant to be described, it is described as being bright. What do we want ? We want " a place in the sun." When we are depressed, or whenever somebody is anxious, what we do talk of ? We talk of " the dark care that sits behind the horseman." It is not " the light care," it is " the dark care." The psychological effect of light then is by no means to be neglected. It has a very important effect. Look at the faces of the slum dwellers, even when they are well-fed ! Take the children, and compare their faces with those of children in the country ! I do not think you need any further illustration.

There is one point in relation to the sun that I wish to make which I am very glad to see Professor Leonard Hill did not mention. I am glad he left me a little bit, anyhow. I refer to some work that has been done in Columbia University, U.S.A., on the seasonal changes of the blood. There has not been any great confirmation of this so far as I have seen, but it is a most important contribution to scientific work. It has been shown that the calcium and phosphorus content of the blood is at its lowest at the end of winter, about March, and at its highest about the end of the summer or in the autumn. The conclusion is almost irresistible. If I remember aright, the actual conclusion arrived at by the contributors of this work is that that is directly the result of the greater light in the summer period. It is the summer period that stimulates the whole organism to greater activity, and the phosphorus and calcium content of the blood being increased it is quite likely that we may find there are other chemical and physical changes, which will be demonstrated before long as a direct result of the seasonal climatic alterations of the year.

Tuberculosis, rickets and septic conditions are probably the three main groups of disease which have been directly tackled by sun treatment or heliotherapy. I need not say much about rickets. Professor Leonard Hill referred to the subject very fully. The work of Dr. Harriet Chick, in Vienna, which is well known to many of us, demonstrated fully the fundamental importance of the sun in the treatment of this disease. Even if vitamins are practically absent from the food of a child, sunlight can prevent the onset of rickets. With regard to tuberculosis and sepsis, I would only say that we have in Leysin, in Alton, Hampshire (England), and to a very small extent, an extent which we are hoping to increase very soon, in Abergele at the Manchester Sanatorium, actual demonstration of the beneficial effects of solar radiation. At Leysin perhaps the most

impressive thing, just at the first glance when I was there, was to see white men and women in their respective verandahs—they were prepared so that we might see them—who were literally black. They were so deeply browned by exposure to the sun that their skin was the colour of a midwinter football. Not only that, but, on a further investigation of the cases, we saw the general records, the X-ray photographs of the cases from the beginning, and their gradual progressive changes as they proceeded to cure. We saw cases there in which the spinal column had been quite half eaten through by this disease. There were several marks on the back of a single patient due to abscesses from these disease-foci. Yet the medical man of the Sanatorium, who showed us round, could thump the patient vigorously on the direct site of the disease and the patient only laughed. This was not only the case with spines, but also with hips, bones, joints, and glands of all kinds. Abdominal tuberculosis responded remarkably to treatment. I could personally speak of a lady who had gone from London for the " sun " cure, not because of tuberculosis, but because of persistent septic conditions of the throat and neck. She was looking absolutely the picture of health when I saw her, and she had no kind of treatment except sun, no drugs whatever. They do not use drugs. They never operate on abscesses. Abscesses are left to be cured by the sun. The knife is gone, in so far as the Leysin system of treatment is concerned. Similar results are obtained in England. It does not need, necessarily, the Swiss climate. At Alton, in Hampshire, Sir Henry Gauvain shows quite as wonderful results. In Abergele, our own sanatorium in North Wales, where we have an extremely small number of beds for children at present, we hope, this winter, to commence a considerable extension. At the present moment, we have only about a dozen beds for children, but, there, I have myself seen and watched a case—I am talking of an actual case—where the hands, feet, cheek, and ankles were all tuberculous. That child went out running about as cheerful and as happy as could be a year and a half later. There was not a scrap of disease discernible on the body ; every scar well-healed, and every limb supple and sound ; nothing wrong with it at all. That is only one case. There are any number of others. I took some people out there not long ago to see the cases, and they were absolutely astounded at the results.

That is in our own islands. We can get the results perfectly well.

I would like to make one reference to bovine tuberculosis. Why we should restrict the beneficial action of sun and air to our consideration of human beings I do not know. The cow is the source of supply of most of our food for infants and young children. We ought to take as much care of the cow as we do

of ourselves, and yet, throughout the country, we have cows housed in the most dreadful conditions. Many cowsheds are black as night, with never a chance of any sun-rays penetrating —conditions directly favourable to tuberculosis. These animals are the source of the food of the children of our race ! Is there any wonder we are a C3 nation ?

The following charts illustrate certain points in the local conditions, but do not pretend to give a complete picture of the relationship of absence of sunlight or the presence of fog to disease.

In Chart No. I. we see that Manchester, compared with Southport, Rhyl and Bournemouth, exhibits a maximum amount of sunlight in the city for the summer months only a little higher than that experienced in the winter periods in those other places. The very low records of sunlight in the city would undoubtedly mean a still greater lack of ultra-violet radiation.

Chart No. II. shows on the right hand side the sunlight at Timperley, a place within six miles of Manchester, taken as 100 per cent. The other sections coming towards the left show the percentage of light in the various centres of the city, exhibiting to a marked degree the loss of light which industrial conditions entail within very short distances.

Chart No. III. shows how respiratory diseases and sunlight occurs in inverse ratio.

Chart No. IV. is especially interesting inasmuch as it demonstrates clearly the direct rise of respiratory deaths consequent upon fog, and the general rise of respiratory deaths in the sunless period of the year.

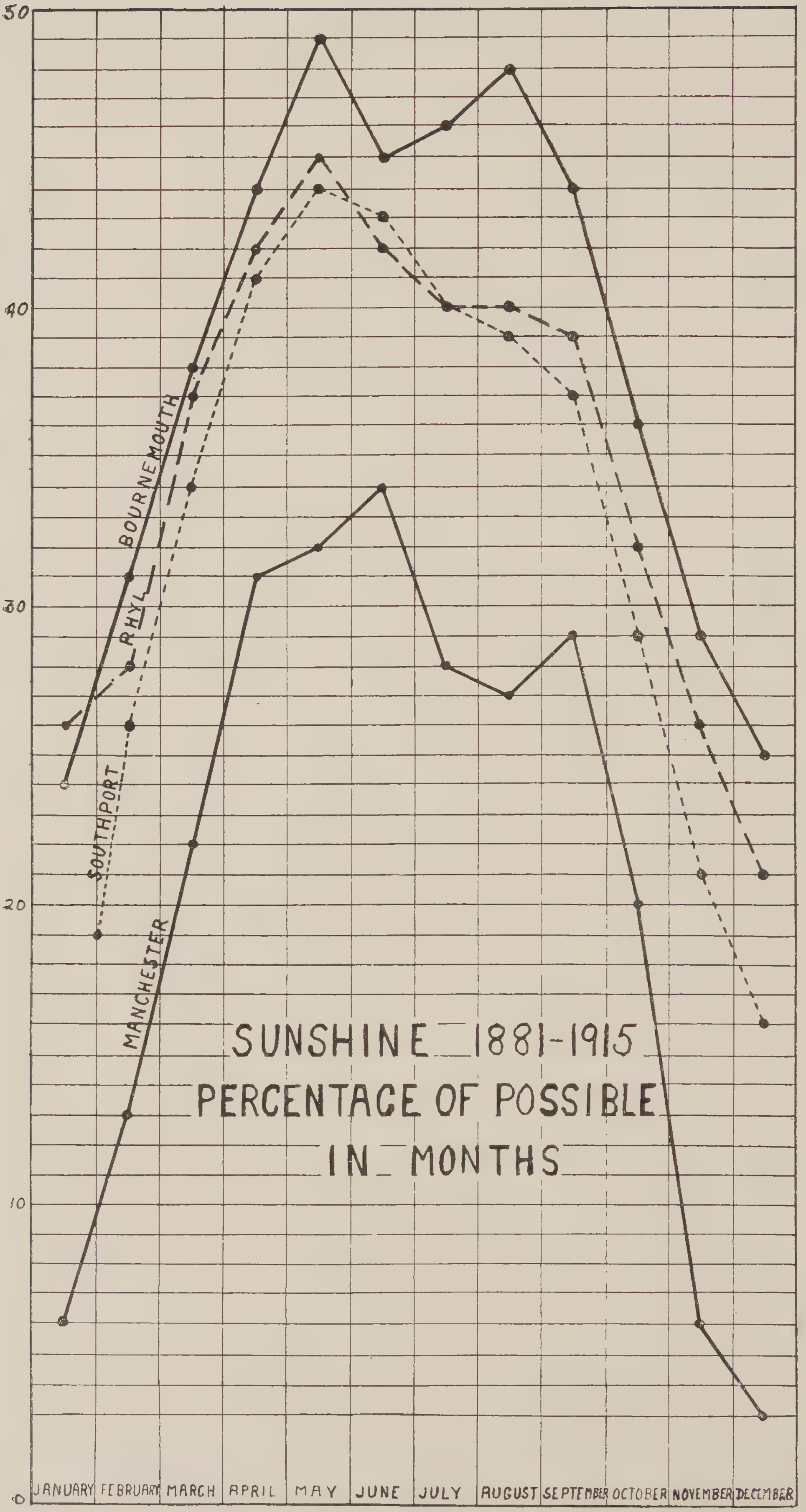
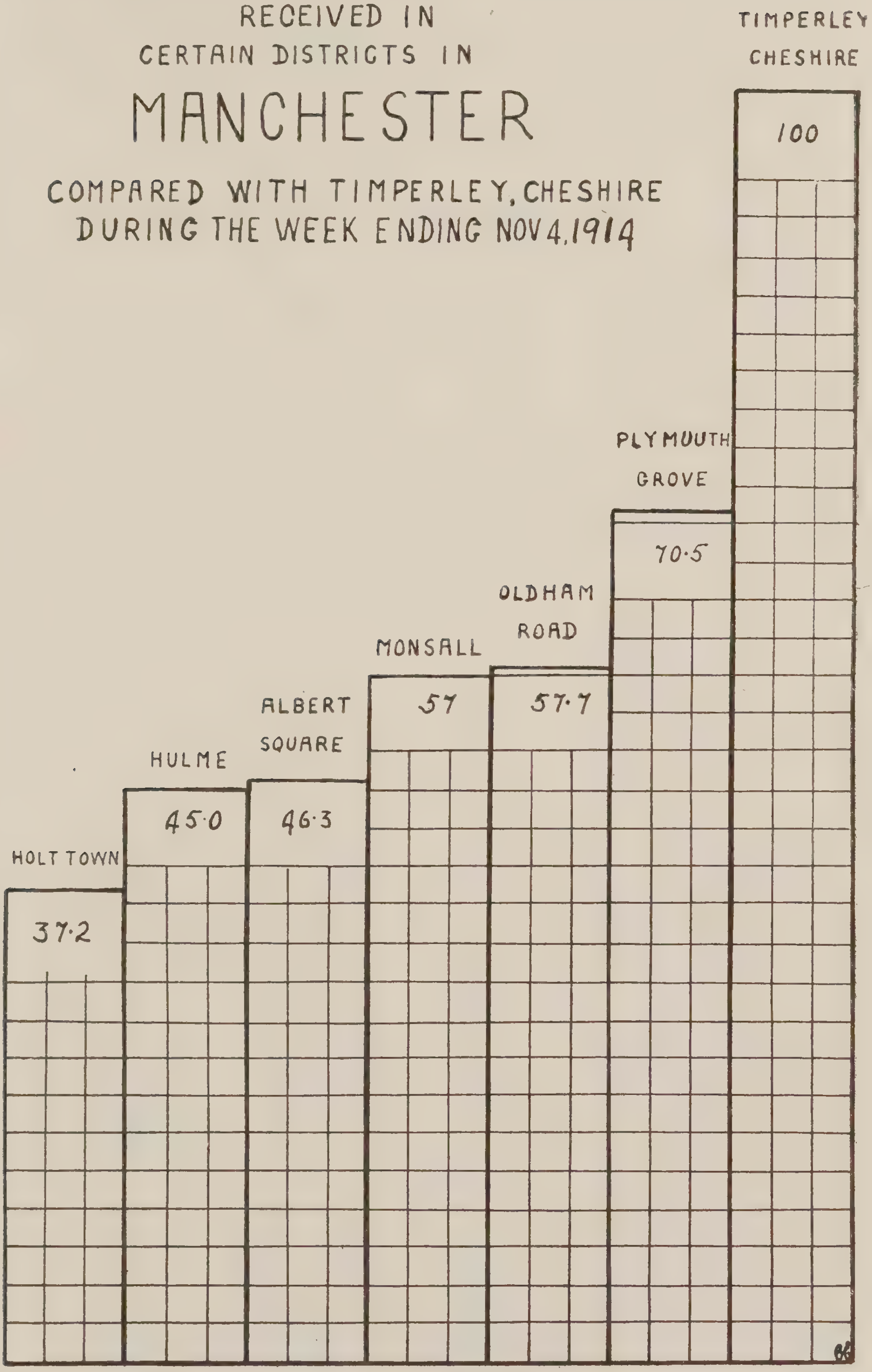

50
40
30
20
10
0
BOURNEMOUTH
RHYL
SOUTHPORT
MANCHESTER
SUNSHINE 1881-1915
PERCENTAGE OF POSSIBLE
IN MONTHS
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER

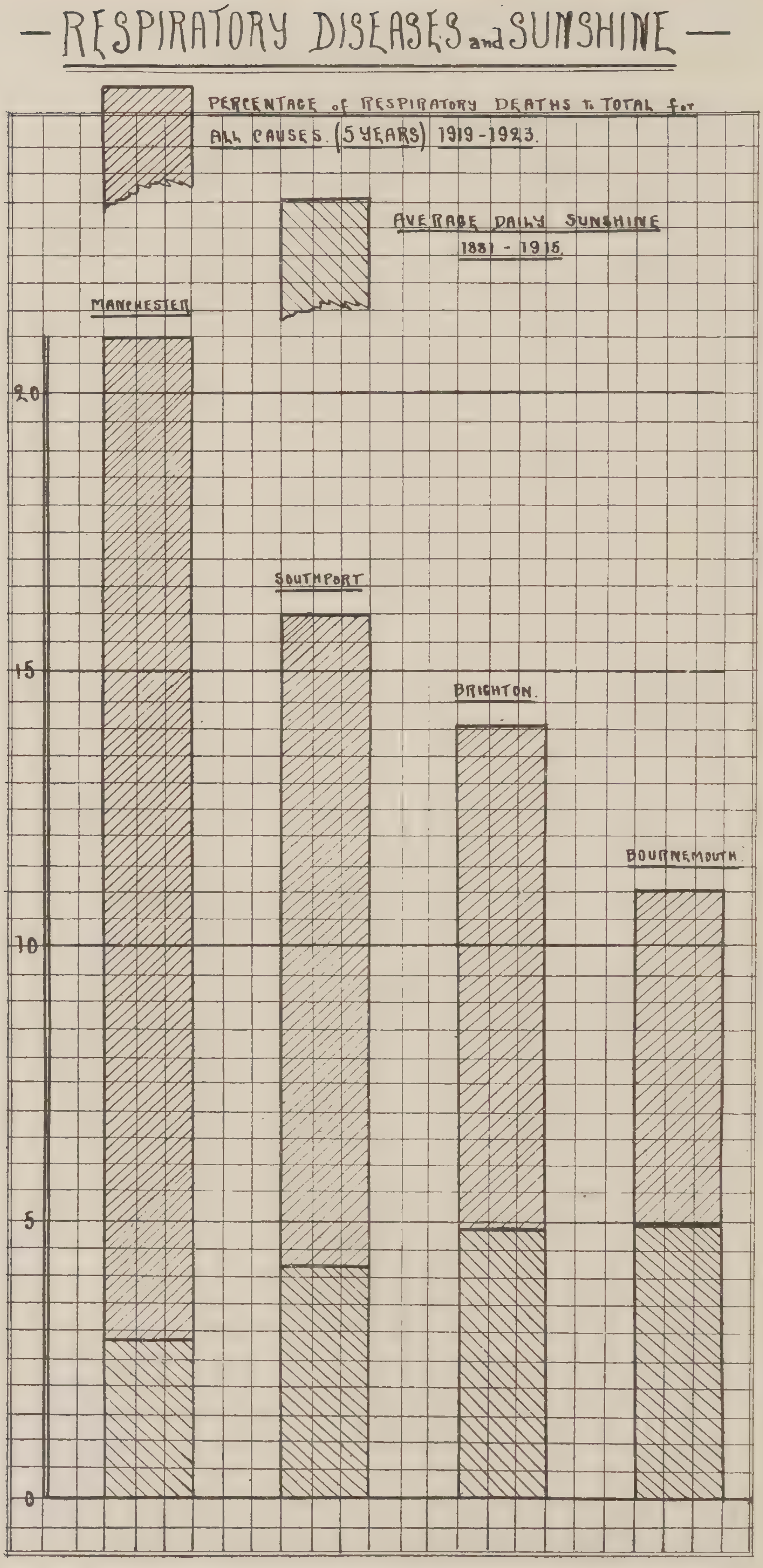
Chart No. I.

PERCENTAGE PROPORTION OF LIGHT
RECEIVED IN
CERTAIN DISTRICTS IN
MANCHESTER
COMPARED WITH TIMPERLEY, CHESHIRE
DURING THE WEEK ENDING NOV 4, 1914



WEATHER CONDITIONS VERY SIMILAR, BUT ONLY CLEAN WHITE MIST
AT TIMPERLEY UP TO 9. A.M

Chart No. II.



— RESPIRATORY DISEASES and SUNSHINE —
PERCENTAGE of RESPIRATORY DEATHS to TOTAL for ALL CAUSES. (5 YEARS) 1919-1923.
AVERAGE DAILY SUNSHINE 1881 - 1915.
MANCHESTER
SOUTHPORT
BRIGHTON.
BOURNEMOUTH.
20
15
10
5
0

Chart No. III.

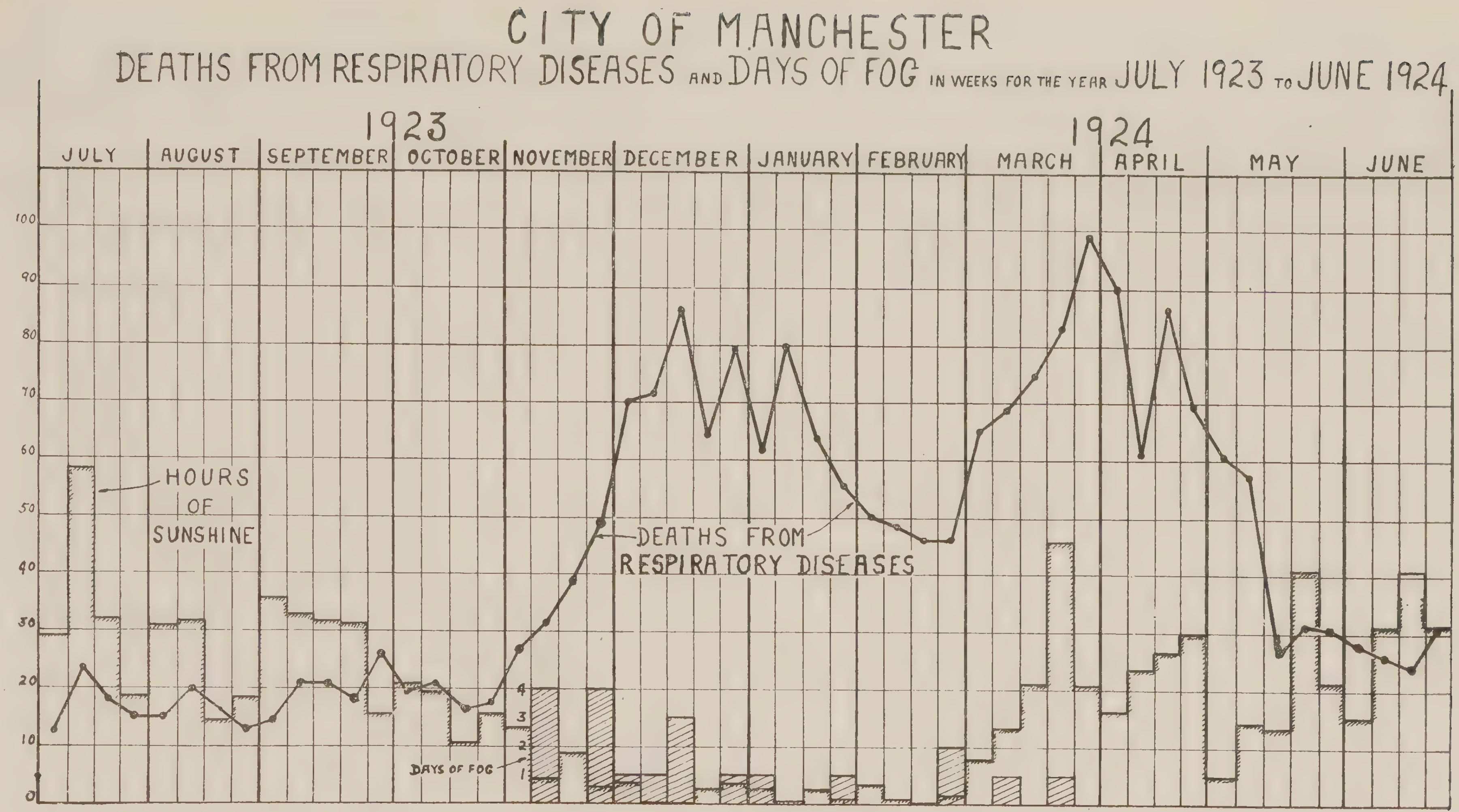

CITY OF MANCHESTER
DEATHS FROM RESPIRATORY DISEASES AND DAYS OF FOG IN WEEKS FOR THE YEAR JULY 1923 TO JUNE 1924
1923
1924
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
100
90
80
70
60
50
40
30
20
10
0
HOURS OF SUNSHINE
DEATHS FROM RESPIRATORY DISEASES
DAYS OF FOG
4
3
2
1

Chart No. IV.

The CHAIRMAN said he was sure the audience were delighted with the two papers. Both were very instructive and contained many things that were novel; they must have been quite new to many of those present. But the main part was old. The indictment of the smoke nuisance was not new, and there was something else which was not new, the apathy of the public, which was very old. Some thirteen years ago he gave an address in this hall on this subject, in which he made remarks about this want of interest. He supposed he meant the Manchester public, but certainly the London public was very nearly as apathetic. It was an old saying that what Lancashire thinks to-day the rest of the world will think to-morrow, but in the matter of Smoke Abatement the Manchester public was very dull and stupid, as dull and stupid as the atmosphere outside. On this question why could not Manchester and the big towns in the neighbourhood rise to a consciousness of the nature of this awful evil? Why had men like Professor Graham and Mr. Elliott to go on hammering and hammering away to get a paltry £100 in a rich place like Manchester to forward a municipal crusade? Last night they had heard the indictment of the effect of smoke on public buildings, to-day the effect on health. They could go to Oxford and see every college damaged by smoke, yet the Oxford public was indifferent! Could no one wake them up? He had been trying for thirty years and his success had been small, and all he could say was that apathy to-day was slightly less than formerly. At first they were met with ridicule and contempt, and for years no converts were made. He had once said that the people in these islands, taking them as a whole, were uninterested and even hostile, and he thought that remark almost as true to-day, although it was made years ago. Was there any one present who could exorcise this insensibility, which he could not understand? His audience looked as if they were fed on the diet which Professor Hill had recommended; their aspect was one of health, and their complexions were rosy, showing no sign of the deleterious effects of the atmosphere. They could get away for "change of air." But the real sufferers were those who could not go away when they pleased, and their indifference was due to a life-long stoicism.

Colonel F. R. McConnel asked whether any steps had been taken to carry out scientific research in order to find a cure for minor obstructions to the ultra-violet rays. The great obstacle was undoubtedly the terrible blanket of fog and smoke, but there was also the way in which we loaded ourselves with garments which kept out the sun's rays and presumably the ultra-violet rays. Had any scientific research been made to discover with what fibre it would be best to make garments in order to allow light to get through? They had wool fibre, linen fibre, silk fibre, and even artificial silk. Surely it was important to find out which was the best.

Light was kept out of houses by glass which, he understood, was practically opaque to the ultra-violet rays. They had it in conservatories and greenhouses where it was most important to let light in for the benefit of the plants. Was there any research going on as to whether they could have a more satisfactory medium for the passage of the ultra-violet rays?

Dr. Leonard Hill said with regard to the question of clothes, researches had been made at the National Institute of Medical Research. It was not a question of fibre, but of weaving. If the weaving was open enough and one garment was worn, the ultra-violet rays would pass through the holes of the weaving. A bathing suit made of open mesh would let them through. A zephyr would let a considerable amount through. With a fine zephyr it took twenty minutes to kill infusoria in place of five minutes without this screen, but with a flannel shirt they would not be killed in an hour. Women had the advantage with bare necks and arms. Men ought to get rid of collars and wear open-neck garments.

Research was also being made as to glass. Quite recently he had submitted to him an experimental melt of new glass which would allow the ultra-violet rays to pass through. It was quite good enough for skylights. A new monkey-house was being planned at the Zoo, and they were proposing to give the monkeys the benefit of this glass—that is, if the big melt came off success-

fully—and to give them the benefit of the ultra-violet rays from quartz incandescent lamps.

Mrs. Higgs (Oldham) said, speaking from a woman's point of view, she wanted it to be realised what a very recent thing this smoke cloud was. One hundred and fifty years back Lancashire homes were clean, the tables scrubbed white and floors sanded, beautiful sunlight coming in and fresh air. This gave the Lancashire lasses beautiful voices for singing. They had been robbed of clean air, and a woman's life had become a contest with dirt. She wanted the men to remove this disability which weighed so heavily on the Lancashire woman, who still had an instinct for cleanliness, and whose life, because she had that instinct, had become a terribly hard struggle. The population was stunted in stature and often C3 in physique because of the deprivation of sunlight and the deprivation of fresh air. On hospitals, sanatoria and infirmaries, thousands of pounds had been spent. If money had been invested in fresh air and sunlight, this would have done more for the slums and sick of our towns than anything else.

It was a preventible evil. Some little while ago, speaking at Ancoats on health, she was told that what she said on a previous occasion was still remembered. She said they did not wash their clothes in other people's dirty water, but they did go on breathing other people's dirty air,—the dirty air that is being constantly made. The women in Ancoats remembered that, but she did not know whether they remembered to open their windows.

The opening of windows was a difficult question. In Oldham a day or two ago she was asked, " Who was going to open the windows in a street near the gas-works ? " Every morning there was a deposit of grit. They could not open their windows because of the grit that came in at the windows !

Were they going to reckon everything by money ? Was it not true that this absence of sunlight had taken a great deal of the brightness out of life? Was it not a fact that the frantic

rush to Blackpool and elsewhere, seeking pleasure, was partly a consequence of the absence of brightness in life ? In the tanks in a museum the fishes came up to the surface to breathe. That was what the population of Lancashire were doing in this rush to Blackpool. They were like fishes rushing to the surface to breathe.

The countryside also suffered. When her grandchild went to the Lakes at Easter he was astonished to find that he could play without getting dirty ; he could not play anywhere within thirty miles of Manchester, not even on the moors at Hepstontall, without getting black. That was because of the deposit on the countryside ; the countryside was suffering as well as the town. Fresh air and sunshine were God's free gift, and they had destroyed it. So it was a real bit of redemption work, a real crusade, to which they were called. Women could not do it. Women could only ask the men to set to work. If this smokeless fuel which had been spoken of was made they would take to it and get rid of the smoke from the household fire, but the men would have to see to the chimneys, which were certainly responsible for a very large amount of smoke.

Mothers were the greatest sufferers. From the little streets where life was spent in a contest with dirt the mother and the little child could not escape. Why were so many of the little children of five years age who reached the schools already suffering ? It was largely because the mother and the little child were forced to live in little back streets without fresh air and sunshine. They must try to save the suffering mother and child.

One thing she recommended very strongly. If branches were formed in different towns, as she hoped they would be, do not call them local branches of the " Smoke Abatement League of Great Britain," but call them " Fresh Air and Sunshine Committees." By dwelling on the ideal, by dwelling on " fresh air and sunshine," they would get double the amount of support that would come to them if they talked about " the smoke problem."

Mr. Evan Roberts, Junr., thought Mrs. Higgs had hit the nail on the head. In the Manchester and Salford Sanitary Association their experience was that they might go and talk about smoke abatement, but it would have little effect if they could not offer the people smokeless fuel at a reasonable price. As soon as the town councils would produce in their own areas the smokeless fuel at a reasonable price they would get the public to use it.

Councillor Kendall (Manchester) said although he had been for a good many years connected with the Manchester Town Hall and with public work, this was the first time, so far as he could remember, that the Medical Officer of Health had really stirred him on this burning question. Just think that over. How many medical officers of health throughout the country were there who were making this a burning question? He was a member of the Air Pollution Board at Manchester, but it was the first time he had realised how important a Board it was. Members of the City Council were not keen to serve on it; they regarded it as a sort of crank's idea. After what they had heard that evening it was evidently true that this was the most vital question they had to deal with as a public authority.

The Chairman: It is.

Councillor Kendall said the committee which had this matter in its hands, whether it was called A Fresh Air Committee or some other name, should be the most important committee of the municipality. If what they had heard that evening was correct, and nobody doubted its correctness, they had got to see to it that the city took its proper position. He was very glad that Dr. Veitch Clark had committed himself in this whole-hearted manner. He himself was a member of the Health Committee, and he was going to watch for Dr. Veitch Clark to move them along; there was now quite sufficient justification if for twelve months Dr. Veitch Clark talked of nothing else. They had been told of the effect on those little lads at Abergele. There were hundreds in Manchester waiting to have the same beneficent treatment accorded to them. No member of the Corporation could devote himself to a greater or more humane service

to the public than by making this a vital question. He hoped one result of the Conference would make them all feel this question had got to be taken up whole-heartedly, that they had got to see whether they could not vitalise the committees which had been entrusted with important work into more vigorous action, and impress upon the municipalities the importance of this service.

A great difficulty in connection with the work was that in the municipalities a large number of the members did not realise that this was an economic question. They looked upon the expenditure of the money that was required as simply carrying out the ideas of certain cranks. Once these people had been impressed with the idea that there was money in it, one of the greatest difficulties would have been got over. His experience was that nearly everyone on a committee looked upon a thing from the point of view of pounds, shillings and pence, and if they could not be convinced that the city was going to get something out of it they would turn it down, but if they were convinced that the city would gain in health, vitality and efficiency they would commit themselves to the expenditure. He hoped that would be one of the results of the splendid Session that day.

A Speaker mentioned the Jewish Fresh Air Home at Delamere Forest, and pointed out that if such an institution could be established by so small a community as the Jews a much more ambitious scheme could be carried out by municipal effort.

Dr. Veitch Clark said there were two sanatoria in the Delamere Forest region. One was called the Delamere Sanatorium, which belonged to Liverpool; and the other was the Crossley Sanatorium, which was attached to Manchester. Both those institutions, he thought, only treated diseases of the chest—ordinary pulmonary tuberculosis—and did not carry out the sun treatment. The sun treatment was practically restricted in its efficacy at present to the non-pulmonary types of tuberculosis.

The previous speaker remarked that he had understood the sun treatment was carried out at the Jewish institution.

Mr. F. W. Goodenough said the papers to which they had listened were examples of the wonderful unselfishness of the medical profession. Dr. des Vœux had given his time freely, for the last twenty years, as Treasurer of the Coal Smoke Abatement Society, to the work of trying to prevent diseases, the cure of which was the living of the medical profession. In other words, medical men were working to abolish their profession, as far as it was possible, by preventing disease. As other speakers had pointed out, sunshine was not merely the curer of diseases; it was also the preventer of disease. If people would only live under the natural conditions created for them there would not be disease to cure.

He would like to say a word of consolation to Dr. des Vœux, who was very troubled about the apathy of the public on this subject. He himself did not think the apathy was as great as Dr. des Vœux thought, but the public was acting rather than talking about it. There had never been such a general increase in the use of smokeless appliances in the homes of the people in the great city of London—and he believed it was equally true of the country as a whole—as during the last two or three years. Every year showed a progressive increase in the installation of gas appliances in the place of coal fires. It was an interesting fact that the lead in that direction had been given in London, as elsewhere, by the medical profession. In the city of London the highest consumption of gas per acre was in the district of Harley Street and Wimpole Street, the district which was occupied by the leading physicians and surgeons of the country. He thought that was the most complete answer to the question recently raised by a medical officer of health. He referred to a report published recently in which a great deal of stress was laid upon the amount of carbon monoxide in the flue gas passing up the chimney from fires, which had no effect whatever upon the atmosphere of the rooms in which the fires were used. When he recently went into the consulting room of one of the foremost surgeons in Wimpole Street that eminent man was found sitting by a gas fire, and that was typical of the consulting rooms of London as a whole.

Gas cooking stoves and gas fires had done more to increase the hours of sunshine and reduce the hours of fog, and bring down the death rate in the residential districts of this country, than anything else in the past twenty years. People had asked for advice as to how to get smokeless fuel. Let them remember that the gasworks produced two smokeless fuels, gas and coke ; and those were doing a great practical work in the reduction of smoke and the saving of sunlight.

A vote of thanks to the readers of the papers was carried by acclamation.

The CHAIRMAN, referring to the remarks by Mrs. Higgs about the poor woman's fight against dirt, said it was a terrible fight and was continually going on. It had struck him that it had some connection with the fact that English food was the worst-cooked food in the world. The reason was that the woman of the house was so busy fighting against dirt that she had not time to do cooking. He believed there was a great connection between the two, and, to a great extent between those and the other fact, which they were also learning, that the children of the poor were living, to a very large extent, upon tinned food.

It was a part of the question which had never been tackled yet, and he believed if somebody in the position of Mrs. Higgs, who was evidently very interested in the subject, would take up that question and find out how these women were fighting against it, and then start a crusade, it would have a great effect, not only in the prevention of smoke but also the general improvement of the health of the people.

Dr. HILL said, in reply to the speaker who referred to there being money in the thing, he would point out that there was abundant money both in prevention and cure of disease. They had been extending the arc light bath treatment and found in this a remarkable curative effect on many conditions other than tuberculosis and rickets.

Sixth Session of the Conference

WEDNESDAY, NOVEMBER 5th, 1924.

CHAIRMAN : Mr. DANIEL ADAMSON, M.Inst. C.E., M.I.E.E.
(Vice-President of the Institution of Mechanical Engineers).

SMOKE ABATEMENT FROM THE MECHANICAL ENGINEER'S POINT OF VIEW.

The CHAIRMAN said they had heard about the pressing desirability of preventing smoke and improving the quality of the atmosphere of Manchester. That evening they were hoping to hear something about how the mechanical engineer would help to achieve that end.

The following papers were then read :—

Complete Gasification of Coal

by T. ROLAND WOLLASTON, M.I.Mech.E., M.S.C.I.

The invitation conveyed to me by Mr. Dempster Smith, Sectional Hon. Secretary to the Institution of Mechanical Engineers, was to prepare a paper for this Conference on " Gas Producers—their relation to the Smoke Problem." I had considerable hesitation in accepting this invitation. For ten years or more I have devoted much time to fuel economy through the apparatus commonly known as the Gas Producer, with the valued co-operation of some half-dozen of our fellow townsmen, for whose assistance I can never be too grateful. My hesitation rose out of the fact that one cannot give an account of one's work without at least the suggestion of self-advertisement ; of unduly boosting plant for the inception and design of which one is responsible. I have to ask you in the first place to acquit me of any such intention. I am trying to give you facts and impressions as I see them.

It is not my intention to attempt to deal with Gas Producers in scientific detail. Those attending this Conference are representative of many sections of the community, social, industrial, and artistic, as well as scientific and technical, and I hope I shall express myself so clearly that all of these will be able to follow.

I hope also I shall be more explicit than many who have written and spoken, not always disinterestedly, upon fuel and power problems, and who have left in the mind of the non-technical public wofully distorted and confused ideas. Some of these, writing and speaking with Government authority behind them, have done more to confuse issues than one cares to contemplate. Between the years 1916 and 1920 we, as a community, encouraged by certain more or less notorious demagogues, seemed to lose our balance entirely over certain fetishes, for example, " Organisation," " Mass Production," and " Low Temperature Carbonisation." With the first two we have no concern just now, but I think more nonsense has appeared in the daily press on the possibility of low temperature carbonisation of coal than upon any other subject. There are, broadly speaking, two methods of gasifying coal and two only: one by heating in externally-fired retorts, the other by incomplete combustion in gas producers. There are many variations of both these as determined by the results or products for the moment most desirable, but, by the term " Low Temperature Carbonisation," retorting is always implied and, when associated with the generation of mechanical power, as it so often has been, I say emphatically it is wrong and misleading.

To the extent that *waste* gases from coke ovens or other retorting systems may be used for generating power (as carried out on the north-east coast), the principle is obviously good, but not otherwise. In other words, in retorting systems other than for town's gas, gas may be regarded as a by-product, of secondary importance to coke from coke-ovens, or to smokeless fuel, tar, and its distillates from so-called low temperature carbonisation plants. Please note I am not decrying any of these retorting systems *per se.* Many of them have potentially high commercial value and a great future. The point so often pressed, but which I most emphatically deprecate, is that of their universal association with power and particularly with public supply electricity. I account for its persistence by the fact that most of the exponents are non-technical men, unable to distinguish between one system of gasification of coal and another.

You will notice that I have taken the liberty of modifying the title of the subject allotted to me. Why? A little thought will bring home to all that every furnace for the combustion of solid fuel (or indeed for any fuel other than gaseous) is a gas producer in that the carbon of the fuels is converted to gas by combination with atmospheric oxygen, hydrogen is released before combustion, and ash only should remain. But some of these gas producers (!), for example, the household fire and, in a less degree, the normal boiler furnace, are very bad gas producers.

In the normal gas producer, Plate 1, the sequence of events is supposed to be as follows :—

(1) The hydro-carbons are first distilled and the upper layer of fuel is coked.

(2) The incandescent coke (carbon) combines with the oxygen of the blast air and steam to form ultimately CO (carbon monoxide, combustible).

(3) The moisture or steam of the blast is split up into its constituent gases, oxygen (as above) and hydrogen (combustible).

The resultant gas is therefore a mixture of the following constituents :—

Nitrogen	Inert.
Carbonic acid	,,
Carbonic oxide	Combustible.
Hydrogen	,,
Hydrocarbons	,,

These changes take place through a regulated fuel bed of from two to eight feet deep, in which the raw fuel lies at the top, the incandescent or gasification zone is intermediate, and the whole rests upon an ash base which is systematically removed as gasification proceeds. The blast air, moreover, is carefully moistened, regulated, and distributed, so that in decent practice the gas obtained is regular in quantity and quality.

The processes of generation and combustion of gas constitute two distinct stages, each capable of separate and fine regulation.

In the ordinary furnace or open fire, on the other hand, the generation and combustion of gas are substantially simultaneous and the air control happy-go-lucky.

In a 9ft. 0in. diameter gas producer, gasifying one ton of coal per hour, the volume of blast air and steam may be about 150,000 cub. ft. per hour, and the active fuel bed 3ft. 0in. deep. The actual velocity through the fuel, assuming the interstices to aggregate one-fifth the area, will be about 200 ft. per minute, and the period of contact during which the chemical changes take place, roughly, one second.

Now compare this with an ordinary boiler grate, the area of which, to burn one ton per hour, will be normally about 80 sq. ft. and the average depth of fuel, say, 6in. The volume of primary air passing through the grate will be about 500,000 cub. ft., or the velocity through the fuel on the above basis, say, 500 ft. per minute, and the period of contact less than one-eighteenth of a second.

Mr. Fred Clements, in one of the soundest and most practical papers ever written on the working of gas producers (Proceedings, Iron and Steel Institute, Annual Meeting, May, 1923), says: "The blast should enter the fuel in such fashion that it passes relatively slowly amongst the incandescent carbon, especially in the early stages." Compare this with modern boiler practice in which 50 per cent. excess air admission is considered quite good practice, and, as we know, portions of the grate are frequently quite bare.

These comparisons would seem to be in part accepted by many designers of modern boiler furnaces. The underfeed type of stoker, daily becoming more popular, is clearly inspired by producer experience, and the American stepped grate furnace closely approximates the original Siemens gas producer. If these were worked with thicker fires, and were provided with more definite means of control of primary and secondary air, they would embody most of the features required for producer efficiency.

Mr. David Brownlie recently read to the Institution of Electrical Engineers a paper descriptive of American boiler practice with pulverised fuel. Mr. Brownlie's papers generally raise plenty of discussion and the one in question was no exception. He has his own way of presenting his subject matter, but he does go fearlessly to the root of things, avoiding platitudes and regardless of the fashion of the moment. While I do not agree with all his ideals, I believe he is doing valuable work in his exposition of plain and simple facts derived from direct experience. Mr. Brownlie tells us that, using pulverised fuel, one can work boilers with only 25 per cent. excess air and so gain obviously in efficiency. In his Presidential Address to the Manchester Section of the Electrical Engineers (Institution of Electrical Engineers N.W. Centre, Chairman's Address, 1921), Alderman W. Walker, M.I.E.E., suggests that pulverised coal could be burned with less air and at higher efficiency but for the practical difficulty of keeping "the temperature within the limits which the furnace lining will stand" (say, 3000° F.), and no doubt he is right. The same statement would apply to efficient gas firing. The maximum furnace temperature attainable by proper combustion of coal is probably in the neighbourhood of 5000° F., and until this is attained steadily under boilers there is room for increased thermal efficiency. Yet one learned individual at the recent Wembley Conference suggested that boiler house practice had reached finality. I venture to submit that the limitations of refractory linings are not going to stand in the way of further progress in boiler design, and, with the full knowledge that I shall raise a storm of criticism, I foreshadow the boiler of the future, possibly not unlike our old friend the vertical fire-tube boiler, burning coke or smokeless fuel, and with metallic wetted surface

to take fierce initial temperatures. Engineers of repute are, to my knowledge, thinking on these lines now, but they have powerful commercial influences to combat.

Anyone who will refer to the Patent Abstracts of the last fifty years will observe that the ideas I am putting before you in regard to the combustion of coal under boilers are quite old, and have been the subject of thought and experiment by many inventors.

A good selection from their work will be found in Messrs. Booth & Kershaw's book, " Smoke Prevention and Fuel Economy" (Constable & Co. Ltd.). The point which strikes one in studying this book is that almost every inventor takes the favourite boiler of his day as his standard, and is content to adapt his improved means of combustion to it. I submit that, so far as efficiency and economy are concerned, good combustion of the fuel is the first consideration. First design the best furnace possible and then adapt the heating surface to it. Take, for example, the boiler which may still be regarded as the most popular—The Lancashire. It is a wonderful and beautiful example of mechanical construction, but it is not nor ever will be capable of the highest possible efficiency so long as we attempt to burn coal directly within its necessarily restricted flue tubes.

Let us now consider what the gas producer can do for us in smoke prevention and in purifying the atmosphere. I have tried to show that house fires and boiler furnaces, the main sources of atmospheric contamination, are gas producers, but very bad ones.

When coal is gasified in perfect producers and burnt in perfect furnaces the residual products turned away from the chimney comprise some 19 per cent. carbonic acid, 80 per cent. nitrogen and perhaps some small amount of sulphurous acid gas which cannot be avoided, but these products are invisible and would have none of the deleterious influences which unfortunately we know so well. The gas is as easy to burn perfectly as ordinary town's gas, and the effects would be no more objectionable than if all our fires and furnaces were town's gas-fired and the products turned to the chimneys. What then are the shortcomings of the imperfect gas producers ? In the first place there are coal dust and coke dust, for the broadcasting of which boiler and like furnaces are mainly responsible, and in increasing degree as mechanical draught increases in popularity. Then there is soot, the chief cause of visible smoke and the result of imperfect combustion. This soot will be more or less tarry and greasy as combustion has been less or more perfect ; that is, to imply that house fires are relatively the greatest sinners. The combustible

gases, discharged *as gas* from them, carbon monoxide and hydrogen, are perhaps regrettable rather from the point of view of waste than of hygiene or disfigurement.

Pulverised fuel, rapidly increasing in favour for steam generation and furnace work, gives better results hygienically, in that combustion can be attained more perfectly and there will probably be no tarry deposits nor visible smoke, but, if I am correctly informed, the dry dust and grit nuisance is rather increased.

Though I am a convinced believer in the ultimate necessity of gasifying all coal, I am rather glad that pulverised fuel firing is meeting with some favour, regarding it as a small step in the right direction, one which will inevitably bring us ultimately to gas firing. One might regard pulverised coal as half-made gas, but its use ignores absolutely the potential extraction of valuable by-products.

Gas producers are most largely and very successfully used in this country for firing furnaces in steel works and the like and for driving gas engines. Thousands are at work and, broadly speaking, they are inoffensive from the standpoint of the smoke nuisance, so that, beyond urging that in these directions their use should be extended as far as is economically possible, I need say very little. My aim is to say what I can to extend their use as substitutes for the inefficient and objectionable apparatus to which I have referred previously, the house fire, and the boiler furnace. Our main object is obviously to extract from the coal the utmost yield in thermal units and by-products, but the relative value of these must determine, in each case, what system of gasification should be adopted.

We must first accept the fact that no system of prior gasification of fuel will render available for power or heating quite so many thermal units as direct combustion. We must look, for economy, either to the use under these systems of cheaper fuel or to rebate for by-products, or to both.

The heat obtained from a furnace or producer is usually described as of two classes, radiant heat and convected heat. The radiant heat is thrown out from the incandescent portion of the fire in all directions, and impinges upon and is absorbed by any surface presented to it. Convected heat, on the other hand, is the result of combustion of the released gases and is carried on and distributed by them in their progress to the chimney. If a boiler be fired by a gas producer operating as a separate unit, the radiant heat of the fuel will be largely dissipated in the producer and ineffective in the boiler. There are, however, means, for example, for forming the producer to act as a feed water

heater, superheater, pre-heater of air or the like, whereby most of the radiant heat may be captured. It is along these lines chiefly that we may look for progress.

Again, in a recovery gas producer the gas must be cooled during and for the recovery process. The sensible heat need not, however, be wholly lost, but may and should be entrapped in one of many ways. Producer gas-firing fell into bad repute some years ago, almost wholly due to neglect of these very obvious leakages. I have endeavoured to illustrate this in broad perspective by the graphs, Plate 3.

The gas producer shows a higher yield in thermal units than any other gasification system, and, when the generation of power is the main object in view, whether through the agency of the gas engine, the steam engine, or turbine, there cannot be the least question as to its supremacy over any other gas-fuel system.

I have endeavoured to show in approximately correct perspective in Appendix 1 the relative value of various systems of gas-firing of boilers as compared with direct-firing, in association with modern power stations. The low temperature carbonisation system referred to is only one of many proposed by numerous inventors, and may not be the best in this particular connection. Probably the data which Mr. Robert Maclaurin will give at this Conference will enable me to add something useful to this Appendix.

We need not discuss the gas engine as a power unit here because, in the first place, when otherwise suitable, it is inoffensive as a smoke-maker, and secondly its economics have been the subject of so many earlier papers.

With some diffidence I venture to give you the features of apparatus upon which I have been working for several years, the outcome of realisation that its predecessors could not perform those duties at which we are aiming until certain limitations were removed.

A typical drawing of this producer is given in Plate 2, and in Plate 3 a graphic representation of the results obtained from earlier recovery producers compared with those which, it is clear after two years' experimental work, may reasonably be expected from the new type.

Quality of Fuel.—The normal gas producer requires fuel more or less carefully selected. Caking coals, if not barred, are avoided as far as possible. Very small fuel is troublesome, and high ash and moisture contents are distinctly prejudicial to good working. I give you these fuel limitations very generally because some producers deal with intractable fuels better than

others, but it will not be contradicted that, in ordinary practice, the selection must be more careful, the range narrower, and the price higher even than for boiler fuels. Coke, on the other hand, is always a perfect producer fuel.

In this apparatus the fuel, before dropping into the producer, is subjected, while spread out in thin layers and kept in motion for a period of upwards of 90 minutes in the retort B, to a heating or coking process by contact with the outgoing producer gas. This outgoing gas picks up in its course the more volatile distillates and becomes considerably enriched thereby, and the final fuel fed to the producer is so far coked that, no matter what its original nature, it is of such size and in such condition as to be readily workable, and, due to its then porous nature, workable at very high rates. Two years' practical tests and a somewhat careful analysis over the industrial areas of the country indicate that this producer will work well and easily on small and high-ash and moisture caking fuels quite impossible for other producers or for boiler firing, and costing from 2s. to 10s. per ton less, with a general average of 4s. per ton less.

There is good reason to believe also that this producer will go far to solve the problem of gasification of those high nitrogen fuels, peat and sewage sludge, hitherto neglected on account of the difficulties set up by their high moisture content.

CHARACTERISTICS.—In ordinary producer practice the steam necessary for blast and for driving auxiliary machinery must be generated from some outside source, and should be debited against the producer, while much radiant heat from the gasification zone is uselessly dissipated. In this producer, unlined with refractory material, surrounded by an annular boiler, and provided with a central blast saturator and superheater D, all the steam required (and frequently more) is self-generated. Incidentally, by the cooling agency of these items, clinker formation is prevented even with high ash fuels of low fusion point.

BY-PRODUCT RECOVERY.—Due to aforementioned cooling by useful radiation and to distillation of lightly combined nitrogen during the pre-retorting, the full normal yield of ammonia may be obtained without excessive saturation of blast, and consequently in conjunction with gas showing analysis equal to non-recovery practice. The quality of tar produced is also greatly superior to normal producer-gas tar, but no detailed analytical work has yet been done on these points.

THERMAL EFFICIENCY.—It will be noted that every effort has been made in this design to avoid the sensible and radiant heat leakages common to normal producer practice, and such tests as have yet been possible indicate an average gain of about

20 per cent. in this respect. It will also be noted that these points are attained without complications.

Ash Handling.—This producer may be ashed by hand or by patented mechanism, but, as these have no direct relation to increased thermal efficiency, they are not detailed here.

It will be gathered from the foregoing notes that I regard gas producer experience as helpful towards economical and smokeless combustion in two separate directions :—

(1) The Direct Method.
In individual plants, as providing the best means of firing boilers directly.

(2) The Indirect By-Product Method.
In power station practice, as providing the best means, in the course of generating electrical energy, of recovery of the most valuable by-products of coal.

The Direct Method.—Under the first heading I can most shortly indicate my meaning by reference to a small experimental installation recently carried out and illustrated by Plate 4.

Here we have an ordinary small Cochran boiler with its grate removed, mounted directly over a simple gas producer. Primary and secondary air are supplied by a little electrically-driven fan, both under separate and fine valve control, and the latter preheated by radiation from the gasification zone of the producer, heat which would otherwise partially be lost. Some portion of the same radiated heat might, in larger installations, be utilised for feed water heating, steam superheating, or for all of them. The producer gas generated meets the secondary air at the throat A, and, so far as can be judged, the combustion is chemically near perfection, the temperature being certainly much higher than in any normal boiler furnace. This, however, is not to be feared providing that good water is used, in that the intense heat only impinges upon wetted surfaces. The fuel used is coke.

I hope that the results of tests of this little plant will be available before presentation of this paper, and may be added as an appendix.

There is never any suggestion of visible smoke, and incidental but immensely important industrial and economic advantages are :—

(1) That by simple fan control the boiler is responsive in a few minutes to variable steam demands.

(2) That there is no appreciable fuel waste during stand-by periods.

(3) That the fire will keep alight, and steam may be rapidly raised after week-end or longer stoppages.

I would here refer to apparatus, identical in principle, designed by my friend, Mr. Edgar Mills, several years ago, with particular reference to Lancashire boilers (Plate 5).

It is my conviction that the same principle will be developed on a scale applicable to large power-station boilers in the near future, and I am equally convinced that, economically and hygienically, it will outclass pulverised fuel systems. It is a bold statement to make, but I submit that we only adhere to the use of raw fuel under boilers because we have not the courage to criticise and improve upon modern fashion in boiler design.

There has been recently a considerable amount of controversial correspondence in the technical press regarding possibilities of coke as a boiler fuel. It is admittedly difficult to burn coke advantageously in the normal boiler furnace, but in a producer furnace, such as I describe, it is the ideal fuel.

If smokeless fuel and similar fuels are to come on to the market with the introduction of low temperature carbonisation systems, my submission is that they, along with surplus coke and breeze from other gasification systems, should be used largely in this manner for steam raising.

The Indirect Method with By-Product Recovery.—I submit this as the most perfect, scientific, and economical means of generating bulk electricity possible with modern knowledge. One may refer to a concrete example, the gas distribution system of the South Staffordshire Mond Gas Co. Ltd., with works at Tipton. This undertaking was initiated in 1901, and presents as magnificent and unselfish an example of pioneering as one could easily find. Some interesting figures, kindly provided by the Company, are given in Appendix 2.

I hope I am doing no injustice to the Company in suggesting that this plant, 20 years old, could not supply gas to a large power station at a price which would compete to-day with direct firing ; but I am confident that, due to recent invention and development, a system on similar lines could be put down at the pit-bank, dock, or canal-side to deliver gas to a power station boiler house five or ten miles away, and that, having in view the rebate for by-products, the use of cheap (hitherto discarded) coal, the saving in freight charges, smoke prevention, reliability, cleanliness, and general convenience, it would show substantial economy in most cases. In discussion one generally meets firstly

with the argument of increased capital outlay. It is not so great as one would at first imagine. A prominent consulting engineer, well-known in this district, kindly gave me recently, in full detail, the cost figures of a new local power station boiler house. I have analysed these carefully and would say that, cutting out, as one could, coal bunkers, coal and ash handling plant, forced or induced draught plant, and the costly proportion of foundation and building work associated therewith, the gas-fired boiler house would cost 40 per cent. less, and this 40 per cent. would go a long way towards the cost of the gas plant.

I agree that the cost of laying and maintaining the mains between gas plant and boiler house would be heavy, but very often these would be laid simultaneously with and alongside the condensing water mains, and, the objection to the erection of the power station centrally being in a great measure removed, reduction in electrical distribution costs might often tend to balance.

I ask the engineers present to visualise a station boiler house as clean and neat as the turbine house or switch room, with no ash to handle, no smoke, no dust, and perhaps one man attending to half-a-dozen large boilers. Mr. Brownlie, in his recent paper on pulverised fuel, emphasised the advantages of "remote control" in the boiler house. No one will dispute that gas-firing presents even greater facilities in this direction.

I have attempted in Plate 6 to illustrate graphically the proportionate cross sections of power station boiler houses fired respectively by coal, producer gas, and pulverised fuel. The two first may be taken as correct. The third is admittedly prepared from inadequate data.

Some may regard these views as visionary. I would reply that each claim suggested has been demonstrated individually, and to provide the combination is only a question of assembly. The points of doubt chiefly in my mind are :—

(1) Will the price of ammonium sulphate be substantially reduced by the synthetic processes now coming into use (which incidentally are to a larger extent dependent upon cheap electricity) ?

(2) Will the cost of gas transmission, in cases where plant and boilers are widely separated, be a serious hindrance ? The cost given for South Staffordshire by Mr. Humphrey was ·12d. per 1000 cub. ft., or, say, per 10 KW.

(3) If such methods be extensively adopted, will the price of refuse fuels increase sufficiently to neutralise their effect in reducing costs ? I think not, having in view their relative rates of production and consumption.

May I in conclusion be permitted to foreshadow a complete smokeless programme for future power, heating and lighting :—

Electricity, to be derived from producer gas alone or in combination with some pre-distillation system, generated outside residential areas. The site for gas generation to be selected with special regard to low freight and handling charges, and cheap disposal of ash. The power station proper to be located as centrally as possible with a view to cheap distribution.

Process Steam in Factories, to be generated on the spot by combined producer-boilers using coke only as fuel. In industries where the amount of process steam required is considerable in relation to power required, it is generally agreed that power costs can substantially be reduced. In such cases it would seem wise for factories to generate their own power by pass-out or reducing engines or turbines, taking steam from coke-fired producer boilers.

By this well-known system it is practicable to generate the electrical unit from 5 lbs. of steam as against, say, 11 lbs. of steam required in a modern power station.

Power generally, in industrial areas, to be derived mainly from public electric supply.

Lighting generally to be by electricity.

Heating of Buildings and Hot Water Service.—In densely populated areas contiguous to electrical stations the system originally proposed, I believe, by Mr. W. M. Selvey, of sacrificing some of the technical economy of the steam turbine in working with lower vacuum and in distributing hot condenser water by underground pipes through the area for use in radiators, etc., is worthy of study. Between 40 per cent. and 50 per cent. of the potential energy of coal is wasted in hot-well overflow discharge from power stations, and Mr. Selvey has dealt very fully and attractively with these possibilities.*

Where this method is impracticable one would suggest central heating by hot water radiators, with separate installations for large buildings or centralised systems for groups of smaller houses, the temperature and circulation being maintained by slow-combustion furnaces (which are really gas producers), coke, smokeless fuel or gas-fired. These might be supplemented by electrical radiators in living rooms, not so much for the sake of additional heat as to provide the cheeriness of the hearth for which the Britisher craves.

Without attempting to convert others, I may add that personally I have a strong prejudice against either gas or coke (smokeless fuel) fires in living rooms.

*I am pleased to note that my friend, Mr. Julius Frith, in his paper, endorses this proposal.

COOKING.—Here, on the other hand, I think gas stands alone. Electricity is, I believe, very satisfactory in effect, but simple analysis indicates that economically it must be hopelessly out of the running until power station efficiency is improved considerably beyond the present day figure of, say, 20 per cent.

There is one feature of this programme which distinguishes it from most earlier forecasts, and that is that it " dovetails." To meet requirements economically we should produce from coal: Heat Energy, Hard Coke, Nitrogen Products, Heavy Oils, Light Oils, Benzol, Tar products other than oils. For some of these the demand will exceed the supply for many years. For others the demand will vary from time to time.

It is suggested that the programme foreshadowed in the paper is flexible in this respect to a degree not previously set forth.

APPENDIX 1.

Approximate Perspective of Relative Value of Fuel Systems from Power Station View-point.

Coal 12,000 B.T.U. per lb.

ASSUMPTIONS.

Steam Consumption per KW.	11 lbs.
Thermal Efficiency of Normal Boiler Plant ...	80%
Thermal Efficiency of Gas-Fired Boiler ...	90%
Thermal Efficiency of Modern Recovery Producer Plant	80%
Gross value of By-Products from Producer Plant	12/3
Gas value yield per ton. Town's Gas Plant ...	6,000,000 B.T.U.
Gross value of By-Products from Town's Gas Plant	28/6
Gas value yield per ton Coke Oven Plant ...	2,850,000 B.T.U.
Gross value of By-Products from Coke Oven Plant	28/6
Gas value yield per ton from a certain L.T.C. Plant	9,600,000 B.T.U.
Gross value of By-Products from this Plant ...	16/9
Proportion of gross value of By-Products absorbed in capital charges, stores and labour directly associated with By-Product Plant: Town's Gas Plant	One-third.
Coke Oven Plant	One-third.
Producer Plant	One-half.
L.T.C. Plant	One-half.

Value of electrical unit at Station Switch-board			·65 penny.
Value at works Town's Gas Coke		per ton	28/-
,, ,, Coke Oven Coke		,,	25/-
,, ,, Smokeless Fuel		,,	32/-
,, ,, Sulphate of Ammonia... ...		,,	£14
,, ,, Town's Gas Tar		,,	57/6
,, ,, Coke Oven Tar		,,	57/6
,, ,, Crude Benzol		per gallon	9½d.

	£	s.	d.
(1) A Direct-Fired Normal Power Station.			
Yield per ton, 1480 Electrical Units at ·65d. ...	4	0	2
(2) A Central Power Station at above Served by Recovery Producer Plant at a Distance.			
Yield per ton, 1300 Electrical Units at ·65d. ...	3	10	5
One-half value of By-Products	0	6	1½
	£3	16	6½
(3) A Coke Oven Plant supplying Surplus Gas to Power Station.			
Yield per ton, 170 Electrical Units at ·65d. ...	0	9	2
Two-thirds value of By-Products	0	19	0
	£1	8	2
(4) A Town's Gas Station supplying Gas to Power Station.			
Yield per ton, 372 Electrical Units at ·65d. ...	1	0	2
Two-thirds value of By-Products	0	19	0
	£1	19	2
(5) A Certain Low Temperature Carbonisation Plant, the Smokeless Fuel or Coke from which is subsequently Gasified in Producers.			
Yield per ton, 600 Electrical Units at ·65d. ...	1	12	6
One-half value of By-Products...	0	8	4½
	£2	0	10½

Note.—The figures given above assume the coal used in each case costs the same price per ton. This would not be the case in practice. For example, the cost of coal per ton for No. 2 would be at least 4s. less than for No. 1, averaged over the country, and similar corrections would be necessary throughout.

APPENDIX 2.

The South Staffordshire Mond Gas Co., Ltd.

The Mond Gas Bill authorised this pioneer Company to serve an area aggregating 123 square miles with producer gas for industrial uses only, sale for domestic purposes being prohibited. The works at Tipton were opened in 1905. The rated output then was the gas from 140 tons of coal per day, say, 21,000,000 cub. ft. This is now increased by 80 per cent.

The gas distributed has an average calorific value of about 150 B.T.U. per cub. ft., and is extensively used within this busy industrial district for furnace work of all descriptions and for driving gas engines, giving general satisfaction to all users.

The following figures of cost per 1000 cub. ft. of gas distributed during 1912 are taken from a paper read to the Institution of Civil Engineers, on December 12th, of that year, by Mr. H. A. Humphrey, M.I.C.E., the Company's Consulting Engineer.

		(B.T.U. 150,000)
DR.	Slack for producers and boilers ...	·7913 per 1000 c.f.
	Costs of manufacturing, compressing, distributing, etc., including wages, stores, materials, acid, repairs, and maintenance...	·7043 ,, ,,
	General charges, including Debenture Interest	·8870 ,, ,,
		2·3826 ,, ,,
CR.	By sale of By-Products	1·0956 ,, ,,
	Total net cost of 150,000 B.T.U. delivered	1·2870 ,, ,,

An approximate perspective comparison may be made as between this gas and direct-fired coal, if used for steam raising as proposed in the paper. It may be assumed that boiler slack at that period (1912) was worth 10s. per ton.

One ton of coal, 2240 lbs. of 12,000 B.T.U. value =26,880,000 B.T.U.

As the efficiency of gas-firing compared with coal firing may be taken as 9 : 8, we have $\frac{150,000}{26,880,000} \times \frac{9}{8} \times 120 =$ Relative Fuel Cost for direct-firing = ·754d.

For fair comparison there would have to be added to this figure the following :—

Capital and maintenance charges on, say, 40 per cent. value of normal boiler house.

About 75 per cent. of normal boiler house labour charges.

All extra charges associated with removal and dumping of ashes, etc.

It would seem on these 1912 figures that there would not then have been much to choose between the two systems.

Under present day conditions, having in view improvements of the nature indicated in Plate 3, and the use of cheap refuse fuel for gas making, there is little doubt that, in addition to the advantages of smokelessness, general cleanliness, and convenience, there would be also the prospect of substantial direct economy.

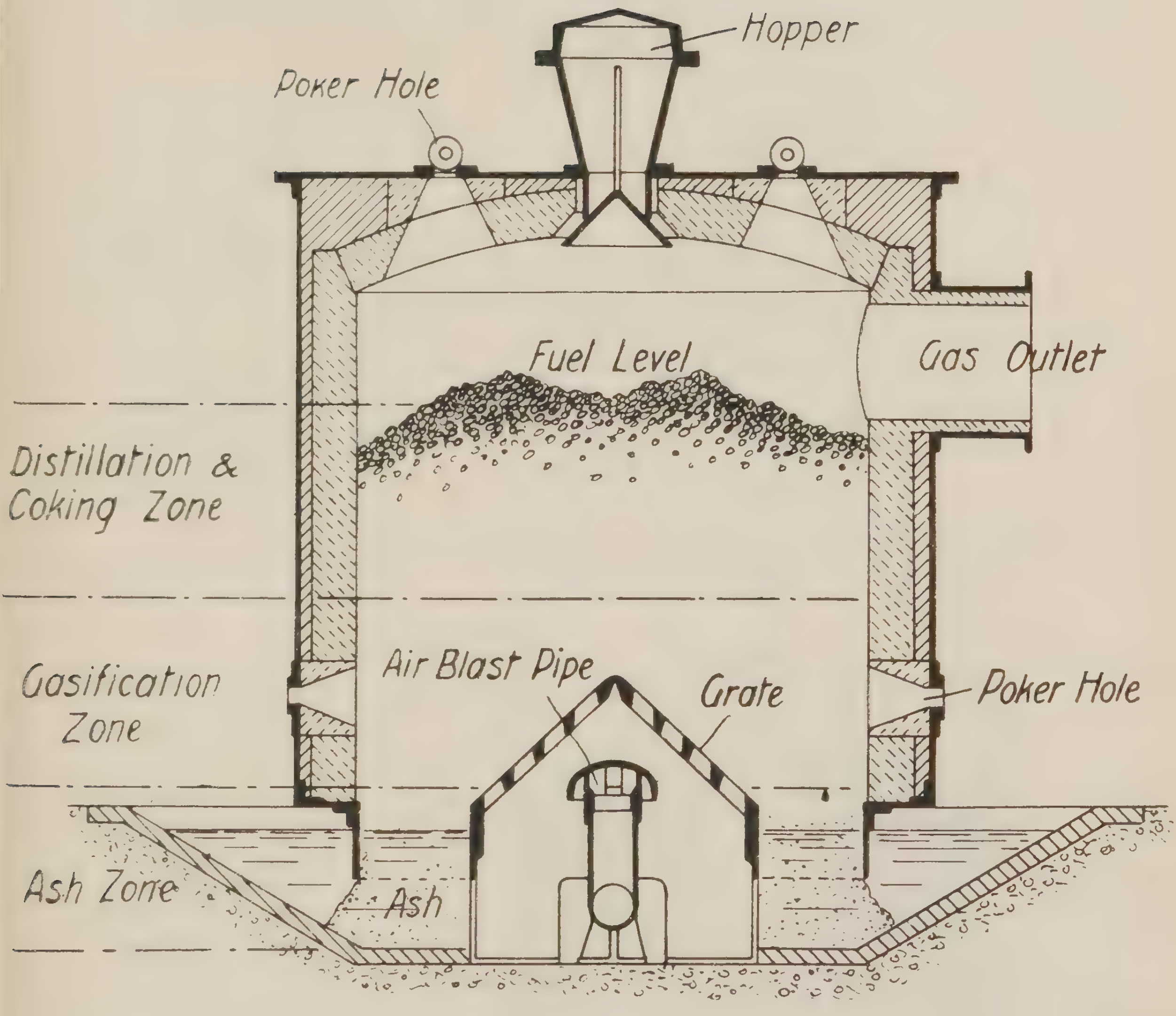
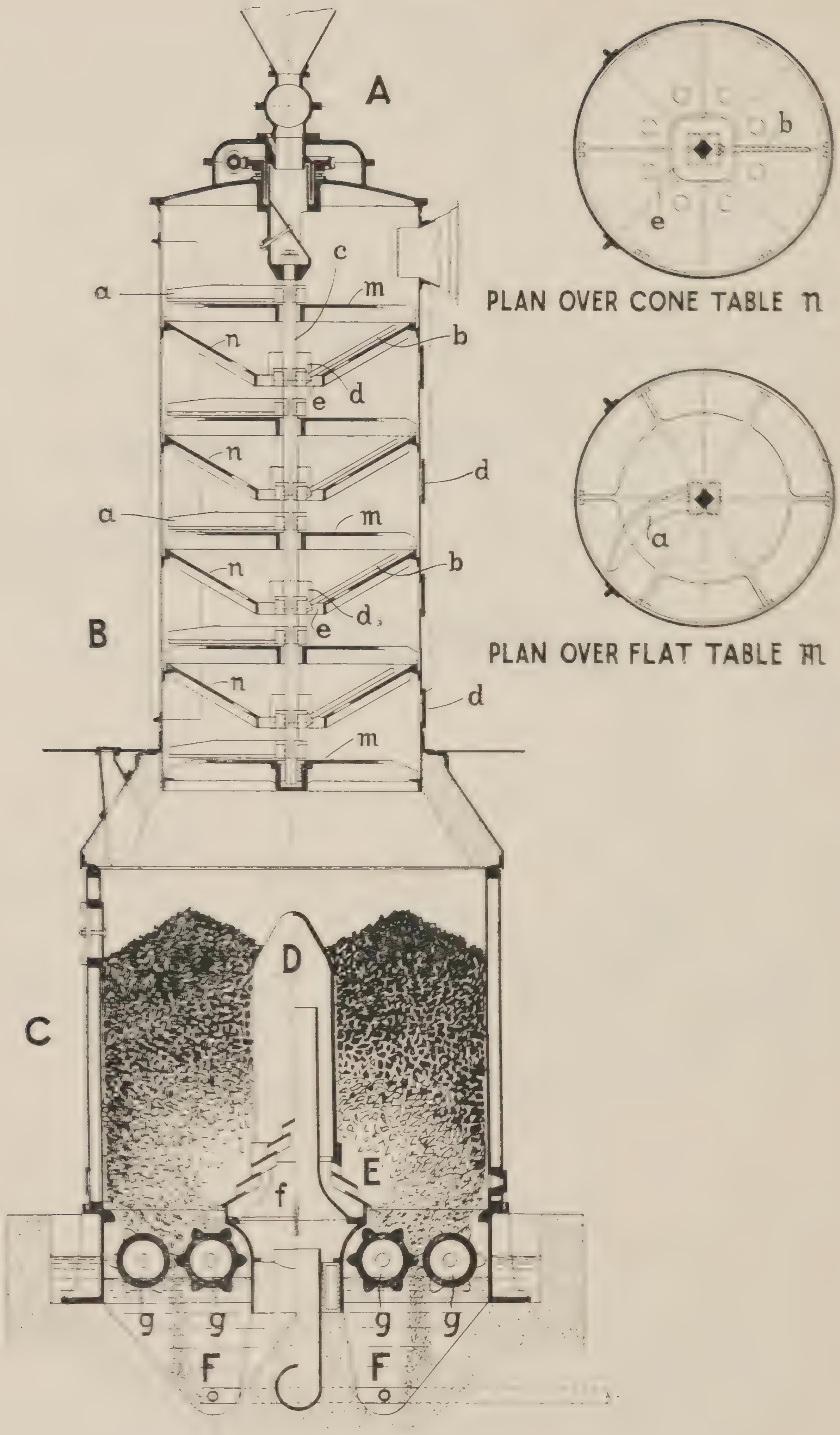


Plate 1

NORMAL GAS PRODUCER


A
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PLAN OVER CONE TABLE n
PLAN OVER FLAT TABLE m

Plate 2

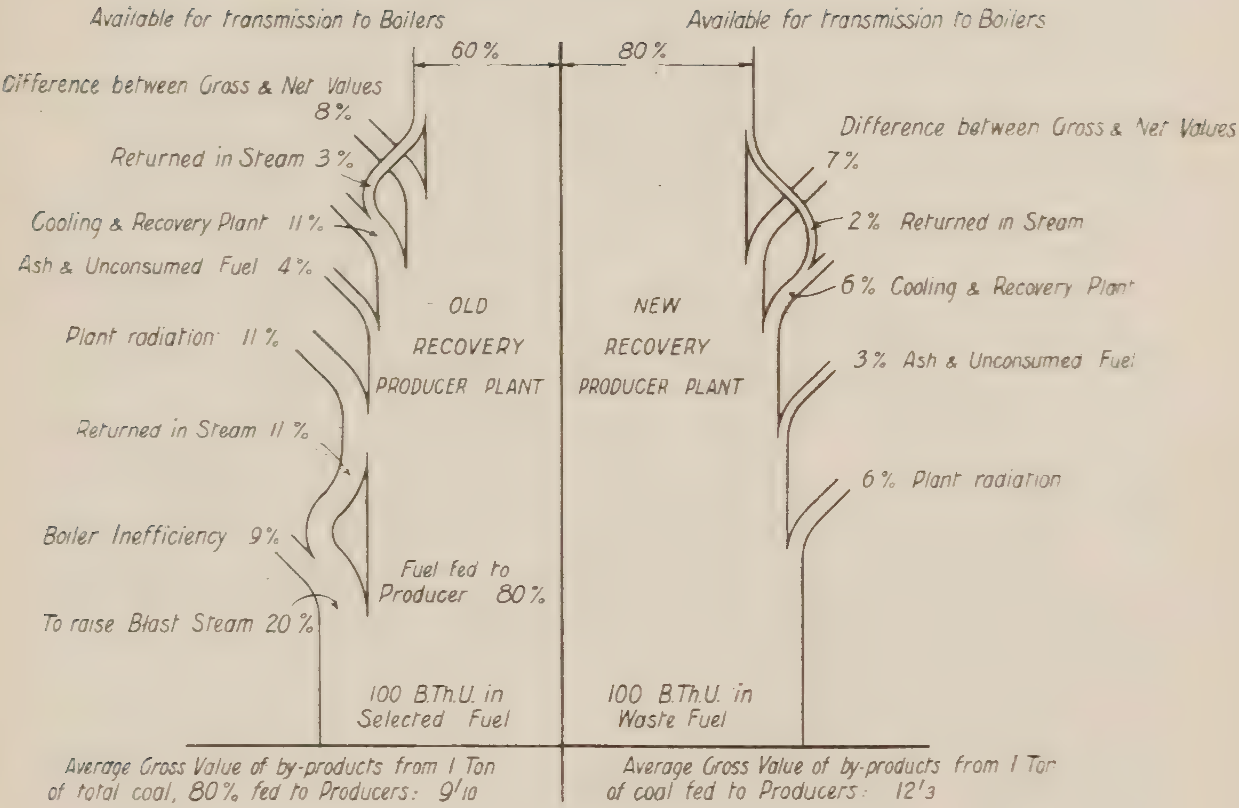


Plate 3

An approximate visualisation of the gain to be expected from a modern Recovery Producer Gas Plant as compared with like plant of ten years ago. The diagram on the left-hand side of the centre line represents approximately the performance of a well-known plant as derived from published figures. The diagram on the right represents, as closely as can be ascertained, the performance to be expected from such plant as is described on page 175 of the paper, and illustrated in Plate 2.

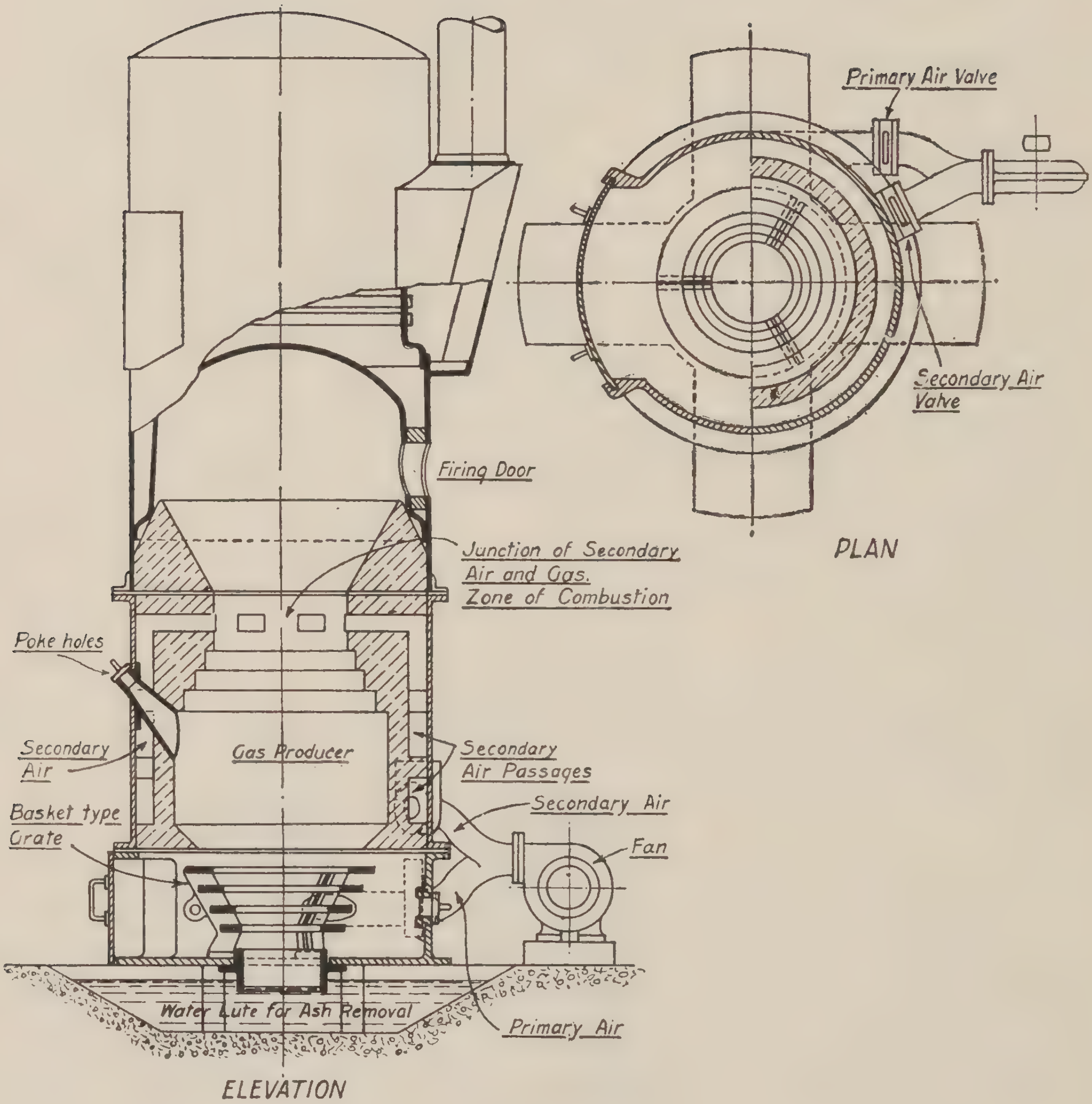

Primary Air Valve
Secondary Air Valve
PLAN
Firing Door
Junction of Secondary Air and Gas. Zone of Combustion
Poke holes
Secondary Air
Gas Producer
Secondary Air Passages
Secondary Air
Basket type Grate
Fan
Water Lute for Ash Removal
Primary Air
ELEVATION

Plate 4

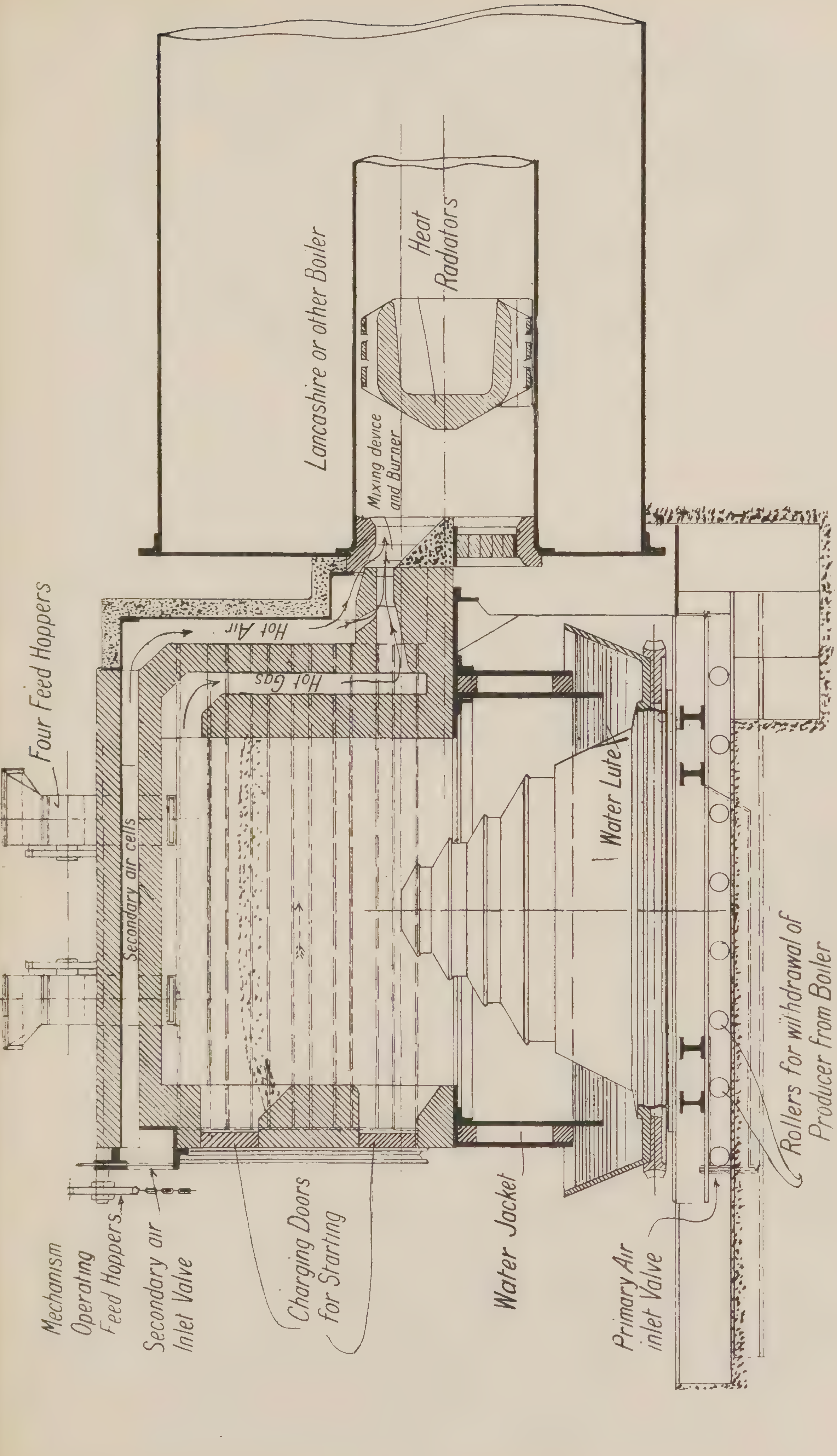


Plate 5

MILLS FURNACE.

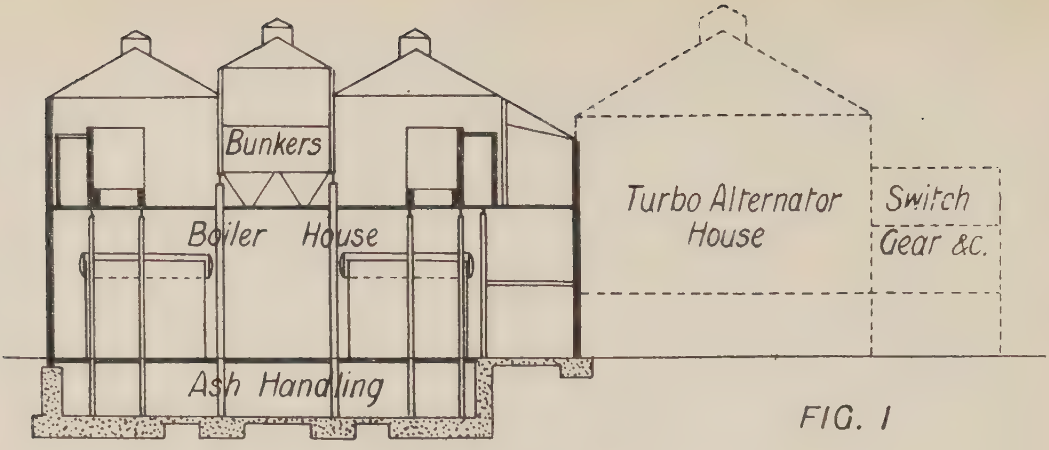
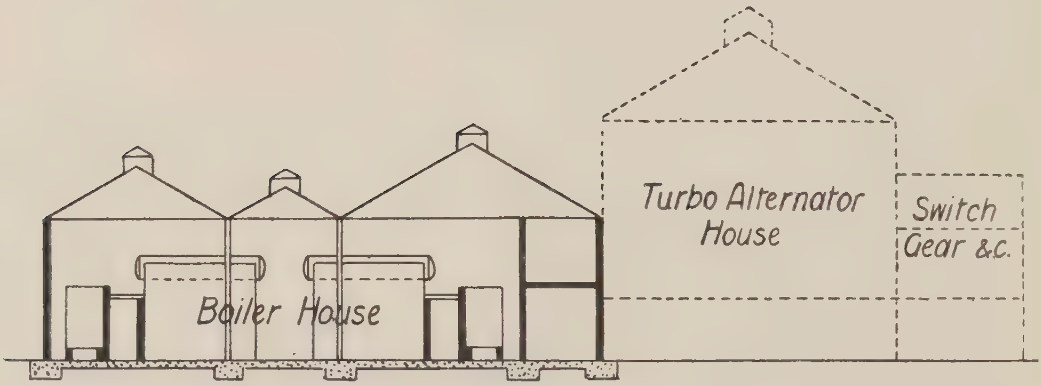


FIG. 1

CROSS SECTION OF A WELL KNOWN LANCASHIRE POWER STATION



CROSS SECTION OF THE SAME POWER STATION ARRANGED FOR GAS FIRING

FIG. 2

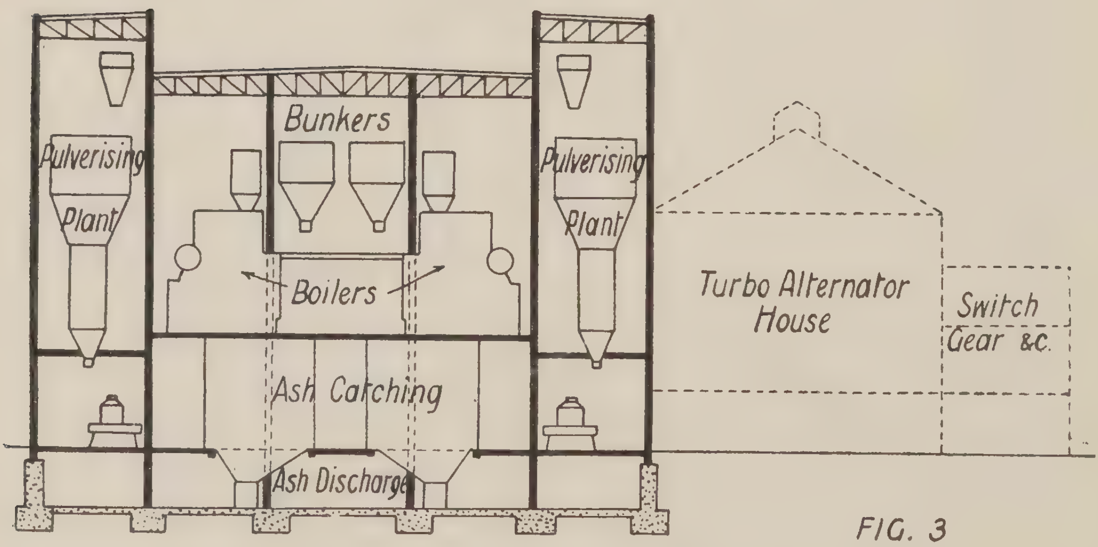


FIG. 3

CROSS SECTION OF THE SAME POWER STATION ARRANGED FOR PULVERISED FUEL FIRING

NOTE: Data for FIG. 3 has been obtained from one of the few published drawings available from American practice. It probably gives an exaggerated perspective for which the Author apologises.

Plate 6

CROSS SECTIONS OF POWER STATIONS

Powdered Fuel and the Smoke Problem

by J. T. Dunn, D.Sc., F.I.C.

Of late years the feeding of metallurgical and boiler furnaces with coal in a finely-powdered condition, instead of using it in lump form on a hearth, has made great progress, especially in America. Before beginning to discuss the bearing of this on the question of smoke abatement, it may be well, for the benefit of those who are altogether strangers to it, to describe the way in which coal is so applied, and the equipment necessary for it. This can only be done here with extreme brevity, and the writer must refer those wishing for further details to his book on the subject, published by Messrs. Ernest Benn, or some other similar treatise.

In a typical installation on what is known as the multiple system, the coal is first broken down (if necessary) by some form of crusher to about inch size or less, and passed over some form of magnetic separator to remove stray iron. The crushed coal is then dried, by passing slowly through a tube or cylinder in which it is exposed to hot air or gases, either produced by a small furnace used for the purpose, or brought from the flues of the main furnace. It is found that the grinding, and more particularly the transport and storage of the coal, are greatly facilitated by having the coal dry, as the finely-powdered dry coal does not clot together, but flows smoothly, almost like a liquid. The dry coal next enters the grinding or pulverising apparatus, in which by means of beaters, rollers, or balls, it is ground exceedingly fine. A current of air carries away all the coal of a sufficient fineness, leaving the coarser portions to be ground further, and the fine coal settles out from the air-current in a cyclone separator and leaves the air to be carried through the mill again, and bring to the separator a further portion of fine coal. From the separator the fine coal falls into a storage bin, and from the bottom of this it is fed into pipes, through which it is transported, either by screw conveyors, by air pressure, or by a combination of the two, to bins at the various furnaces that are to be served. Thence it is fed again into pipes, and, by means of screw conveyors and a portion of the air needed for combustion, is conveyed to the burner and blown into the furnace, where it is consumed.

In the unit system, there is a separate pulveriser for each furnace, which reduces the coal fed to it to a sufficiently fine condition, and then, with the aid of a fan which forms part of the machine, feeds it directly to the burner. As there is no great length of pipe in this system along which the coal has to be driven, and no storage bin, there is much less opportunity for damp coal

to clot and clog the operation of the plant ; accordingly, unit installations usually dispense with the drying plant, and the coal is fed directly from the crusher to the pulveriser.

The coal is usually ground so finely that 95 per cent. of it will pass a sieve of 100 meshes, and about 85 per cent. will pass one of 200 meshes to the inch.

We may now consider whether, and if so why, such a method of burning coal is likely to constitute any improvement on the usual system of burning lump or small coal on a grate, as far as the production of smoke is concerned.

The combustion of coke or charcoal upon a grate causes no smoke. We may look upon coke or charcoal as being practically pure carbon mixed with a certain amount of mineral matter, which is left after the combustion as ash. When the carbon is heated up to its ignition point, it burns with the oxygen of the air and forms carbon dioxide, which is a colourless invisible gas. As air reaches the glowing coke, it gradually lessens in bulk and ultimately disappears, and the product of its combustion is carried off up the chimney invisibly.

When coal, however, which is chemically speaking a very complex substance, is similarly treated, the result is very different. During the heating-up of the coal, long before it reaches the temperature at which it will begin to burn—its ignition point—it decomposes, and gives off large volumes of gases and the vapours of volatile liquids, most of which are by further heating themselves decomposed in turn, producing the black tarry and sooty matters which we know as smoke.

All of these substances would burn if heated to their ignition point and supplied with air or oxygen, and when completely burnt would produce nothing but invisible carbon dioxide and water vapour ; but, evolved as they are in very considerable volume, a considerable quantity of heat is needed for this, and as they are not stationary on the grate, but move on with the air-supply and the products of combustion of the solid fuel, the problem of heating them up with sufficient rapidity and of mixing them intimately with the air needed for their combustion becomes a very difficult one.

Much thought and ingenuity have been devoted to devising means of overcoming this difficulty, and considerable success has been achieved by many of the forms of mechanical stoker now so widely used. The principle on which they mostly depend is the gradual introduction of the coal, and the maintenance of a considerable length of glowing fire-bed, over which the volatile matters and the air appropriately introduced are led. But, whilst

they are satisfactory in normal working, any derangement of the normal conditions of work leads to imperfect combustion and evolution of smoke, and the restoration of normal conditions is always a matter of some time ; and in no case is perfect combustion and smokelessness secured without the introduction of a very considerable amount of air in excess of that necessary for the combustion of the fuel, all of which excess air carries off to the chimney shaft heat to waste, that without it would have been usefully employed.

How are these conditions altered in the combustion of powdered coal ? A cube of coal one inch in the side exposes a surface of 6 square inches, and needs for combustion nearly 7 cubic feet of air—a cube 23 inches in the side. Combustion can only occur at the surfaces where the coal and air come into actual contact, and if we imagine the cube of coal at the centre of its 23-inch cube of air, and suppose the surface to be heated up to the ignition point, we see that all this air must be brought into contact with 6 square inches of coal surface (and this surface will continually lessen as the coal burns away) before combustion can be complete.

Not only so. As the heat from the burning surface penetrates the coal, decomposition begins, the volatile products are evolved, and tend to push away the air from the surface of the coal ; even if the temperature of the surrounding space be high enough to raise these volatile products rapidly to their ignition point, so that they will burn, they have still to find and mix with the necessary quantity of air. The higher this surrounding temperature, the more rapidly will they reach the ignition point ; but also the more rapidly and tumultuously will they be evolved, so that the difficulty of attaining complete mixture with air is not lessened. It is easy to see why excess air is needed to secure complete combustion.

If the cubic inch of coal be powdered so as to pass a sieve of 200 meshes to the inch, the largest possible particles will have a linear dimension of one-four-hundredth inch (for the wire in a standard sieve has a diameter equal to the width of the opening) ; and if for simplicity we suppose the whole to consist of cubes one four-hundredth inch in the side, there will be $400 \times 400 \times 400$ or 64 millions of them, and the aggregate surface they expose will be 400 times 6 square inches : 2400 square inches, or more than 16 square feet. The same air, 7 cubic feet, will of course still be needed to burn this coal ; but if the particles of coal are uniformly distributed through it, each will be at the centre of a little cube of air less than one-sixteenth inch in the side. The combustion of each particle will follow the same chemical process as that of the original inch cube, but because of the minuteness of

the particle, and the close proximity of all the air which it needs, ignition of the particle, evolution of its volatile products, and their combustion in the air immediately at hand, will follow one another so rapidly as to be practically instantaneous ; the cloud of coal dust will burn almost as though it were a gas, and combustion will be complete with hardly any excess of air.

These theoretical conditions are actually realised in powdered fuel installations. The rates of supply, not only of fuel, but of the primary air which is blown in with the fuel and of the secondary air admitted to complete the combustion, can be instantaneously altered or regulated, merely by moving levers which operate valves ; and in a very short time after a furnace is started this regulation can be effected with such nicety that no visible smoke is emitted from the shaft. Once the adjustment is made, such is the constancy and evenness of the process that no regulation is needed, in many cases for hours ; and during this uniform combustion the amount of excess air is found to be from 10 to 25 per cent., whilst in the best mechanical stoker practice there is at least 35 to 40 per cent., and, according to Mr. Brownlie, in average mechanical stoker practice 50 to 70 per cent. of excess air.

The advantage of powdered fuel firing is further seen, however, when any sudden alteration in the conditions of combustion occurs, from a change in the character of the coal, for example. The same quickness and ease of regulation enables the installation to cope with such a change in a few seconds, whilst many minutes would be requisite with grate firing. The writer was on one occasion present when for the ordinary coal in regular use on a pulverised fuel plant an entirely different coal, on trial, was substituted. The amount of volatile matter, and still more the rate at which it was evolved, were entirely different in the two coals ; and as soon as the new coal reached the furnace, dense black smoke began to issue from the shaft. Adjustment of air supply was made accordingly, and in less than half a minute the smoke had disappeared, and the chimney top was as clean as it had been during the regular burning of the usual coal. This possibility of almost instant adjustment to changing conditions is one of the great advantages of powdered fuel firing.

The complaint has been made against powdered fuel firing that, though it may burn coal smokelessly, yet great quantities of fine ash are carried away from it through the shaft, and constitute a nuisance by falling on everything in the neighbourhood. If this complaint were true, it could yet be claimed that such ash from powdered fuel is purely mineral dust, containing no oily, tarry, or sooty matter, and hence is easily and completely removable from anything upon which it may fall. Mechanical stokers throw out dust from the stack ; but this is a coarse dust

of incompletely burnt fuel. Samples which have come into my hands contained from 30 to 55 per cent. of combustible matter, and over 50 per cent. was retained by a 30-mesh sieve, and 95 per cent. by a 75-mesh sieve ; and this does fall in the immediate neighbourhood. The dust escaping from a powdered fuel plant, however, is far finer than this ; in a small specimen measured by Dr. Owens, the largest particles had a diameter of one four-hundredth inch, or would just have passed a 200-mesh sieve, whilst the smallest were little more than one six-thousandth inch in diameter. Such particles, if suspended in perfectly still air, would have a limiting speed of fall, according to a calculation by M. Audibert (Fuel, 1923, p. 148), of about 11 cm. per second for the largest, and probably well under 1 cm. per second for the smallest. It is easy to see that particles of these dimensions, issuing into the air at a height, in a current which at first is strongly upwards because of its temperature, and afterwards exposed to the winds and diffusion currents of the atmosphere, might (and for the most part probably would) be carried for enormous distances and be spread over an enormous area, before reaching the ground.

It is difficult to learn what proportion of the total ash of the coal is carried out through the stack. The proportion must of course vary with the circumstances of the installation ; but at the Milwaukee power station, where careful observations were made over a considerable period, it was estimated that 25 to 50 per cent. of the ash remains in the combustion chamber, 5 to 12 per cent. is caught in the second and third passes of the boiler, 25 to 35 per cent. in the base of the stack, and 12 to 25 per cent. is lost through the stack.

To form some idea of the amount of possible deposit, let us suppose the whole of this ash to be deposited uniformly over a square mile, of which the stack forms the centre. The Milwaukee station, one of the largest in the world, burns about 1000 tons of coal daily. If this coal contains 10 per cent. of ash, and 20 per cent. of this ash is lost through the stack, we have a daily deposit of 20 tons of ash on the square mile. A ton per square mile is rather less than $3\frac{1}{2}$ lbs. per acre, or 5 grains per square yard, so that 20 tons per square mile is nearly 70 lbs. per acre, or 100 grains—less than a quarter of an ounce—per square yard.

But, in fact, the ash is not so deposited. The claim that it anywhere constitutes a nuisance has no foundation in fact. The most cogent proof of the absence of any nuisance from ash so deposited is found in the fact that it is impossible to get any. For the purposes of this paper I have endeavoured to obtain a sample of the dust which had settled in the neighbourhood of a shaft carrying the flue gases from a powdered fuel furnace, in order to ascertain definitely its fineness by experiment. I have

applied to all the installations which I knew ; but none of them has been able to furnish me with a sample, because they have all been unable to find any deposited dust, and I have had to content myself with dust gathered from the flues behind the furnace or at the foot of the shaft, which naturally is coarser than that which escapes at the top of the shaft. At the Ford power station at River Rouge, search has been made on roofs and on the ground over an area of twelve miles radius, but no ash, recognisable as coming from powdered coal, has been found ; and none has been found around the Milwaukee power station, nor has any complaint ever been made there of nuisance arising from it.

At the request of the Powdered Fuel Plant Co., Dr. Owens tried to obtain similar samples from the powdered fuel furnace at the Hammersmith power station. Here, besides the powdered fuel furnaces there are furnaces fired by mechanical stokers, and also hand fired furnaces, and by examining the flue dust from these separate furnaces he found that there were differences sufficient to enable him easily to recognise the dust from any type of furnace and distinguish it from that from another type. He found no deposited matter in the immediate neighbourhood of the station ; but the suspended impurity in the air at places a few hundreds yards to windward and to leeward of the station showed no indication of pollution from the powdered fuel furnaces, and a sample of deposit from a roof about a quarter of a mile to leeward of the station was found to consist largely of matter which came from the hand fired and mechanically fired furnaces, but to contain nothing which definitely indicated that it came from the powdered fuel fired furnaces.

It may of course be urged that whether the dust settles in the immediate neighbourhood or not, it is at any rate blown into the air, and pollutes the air while it is there. The answer to such an argument is that even if it be discharged into the air in such large amounts as to be noticeable, it is yet less objectionable, from every point of view, than the sticky, greasy, sooty, dust which all dwellers in cities know so well. But it is of interest to know that experimental work is being carried on, at certain powdered fuel installations, to find out whether it is commercially practicable, either by electrical precipitation or by washing, to remove the dust, so that the chimney gases may issue into the atmosphere clean.

Among the many advantages that powdered fuel firing presents, then, whether for steam raising or for metallurgical and other furnace work, certainly not one of the least lies in the fact that it enables the combustion of coal to be conducted without the emission of smoke, and effects this easily and without the need for constant watchfulness and supervision. The progress

and growth of powdered fuel firing mean not only economy in the direction of complete combustion and more efficient use of our coal resources, but also approach towards cleaner air and clearer skies.

The Smoke Inspector and the Cost of Production

by H. G. Clinch, M.R.San.I., M.I.H.,
Chief Smoke Inspector, Halifax.

Is the Smoke Inspector a Nuisance ?

By a nuisance, I mean, is he an incubus on the community at large, a source of distraction and worry to the manufacturing world, waiting with wary eye for whom he may entrap into the net of the law, and is he a reasonable business risk ? Or again, is he of incalculable value in promoting the health of the community, and at the same time compelling efficiency in the management of steam boilers ?

In submitting this paper to the Conference of the Smoke Abatement League, my object is to give a lead to a discussion by recognised authorities, on the whole question of the need for an efficient smoke inspection service throughout industrial Britain.

When any great social reform is advocated, two questions invariably are asked :—

1. What will it cost ?
2. Is it worth while ?

No intelligent person will nowadays dispute the necessity of reform in the " Sanitation of the Air," in fact, there are signs of a quickening in the interest of the public on this question. The proverbial man in the street is beginning to ask why he should enjoy the benefits of bright sunlight and clean air during his annual holidays only, and for the rest of the year live in a state of perpetual gloom and choke his lungs with filth.

His wife, also, is beginning to awake to the fact that she is doomed to a life consisting mostly of a long and hopeless struggle against dirt, mainly in the form of soot manufactured at great expense. She is at last beginning to realise the reason of her enormous washing costs, with the consequent increased wear of fabrics involved, and I am confident that she will soon ask why she should be robbed of her hours of leisure, and her home of its brightness, by unnecessary smoke.

The greatest mystery of my life has been the indifference of the people to the question of clean air. An offensive smell,

the presence of dirt in the public water supply, or a dirty tram-car, can always be relied on to raise a storm of protests from would-be reformers who will cry shame on those who misspend public funds derived from the rates. Yet, an atmosphere loaded with dirty, greasy, acid-impregnated solids and vapours, is regarded as a normal state of affairs. In fact, it is no exaggeration to say that, in some districts, it is regarded as an indication of good trade and prosperity. This can only be due to the fact that, speaking generally, the public are ignorant of the evils they suffer, and needlessly suffer, through a smoke-laden atmosphere. I refuse to believe that the people will remain indifferent and silent when they realise that smoke robs them of probably as much as ten years of life, that it exerts a dulling influence on their whole existence, depriving them of the enjoyment of their full vigour, setting up a predisposition to considerable physical and mental suffering, in addition to economic loss through the influence of such abnormalities as depression, fatigue, bronchitis, tubercular disease, and rickets.

To what extent is the smoke inspector able to influence matters ?

At present, the activities of the smoke inspector are confined by law to the black smoke produced by arrested combustion in the furnace of the steam boiler, and opinions differ as to the exact proportion of the total air pollution caused by this particular type of smoke. I cannot agree that the " black " smoke, which is such an alarming factor in the obstruction of sunlight, is emitted by any other than the factory chimney ; the low temperature smoke of the domestic fire is not black, it consists mostly of blue, yellow or even green vapours, a fact which is obvious to any observer. This is emphasised also by the figures of estimated soot deposits issued by the Advisory Committee on Atmospheric Pollution, in which we notice that in London, in spite of the tremendous area and mass effect of the domestic chimney, the soot deposits are at the comparatively low level of about 250 tons per square mile, whereas in our northern towns the figure rises to from 450 to 650 tons. Surely then, we have no further need to search for the cause of the characteristic gloom of the manufacturing towns of Lancashire, Yorkshire and the Midlands, nor need we wonder why nearly 25 per cent. of the population of those towns succumb to " chest troubles."

To what extent, then, is it possible to abolish this " Black Death " ?

Eminent engineers of to-day are repeatedly telling us that the steam boiler can be efficiently worked so as to produce little or no smoke. Government Commissions appointed during the last hundred years have also agreed on this point. I have no

hesitation in saying that the manufacture of black smoke in the boiler furnace is very bad business for those who foot the fuel bill.

Why then, it may be asked, is there any need for smoke inspectors ?

Must it be admitted that, although we are recognised to be, as a nation, the " World's Best Engineers," our manufacturers need the interference of public officials and the spur of the law, in order to induce them to conduct the steam-generating part of their business with efficiency ? In large numbers of cases this undoubtedly is a fact, and it is to our shame that it should be so.

Why is this the case ?

A very careful study of the whole question has convinced me that the average manufacturer is so fully occupied with the technique of his business, and the buying and selling necessarily involved, that he has no time at his disposal for a study of the boiler plant, and is obliged to leave that aspect to others, in some cases being very badly served.

During recent years, I have watched with keen interest the sequence of events following the merging of large numbers of private firms into giant combines, particularly in industries necessitating a constantly varying load on the boilers. The small private firms were content to carry on their wasteful, death-dealing methods to the last, but the combine at once employed the services of highly competent chemist engineers ; and what a transformation followed ! I have seen chimney after chimney cleaned up, not in the interests of public health and the fear of the law, but solely as a result of the adoption of efficient methods. I have for long maintained that the annual inspection of the power plant by a competent engineer would be good business to any manufacturer.

At the present time, the work of the smoke inspector is rendered difficult by the apathy of the public, as reflected in the decisions of magistrates, and also by the total inadequacy of existing legal power. This has led me to adopt the method of giving all the advice and assistance which lie in my power to those concerned ; and by carefully explaining faults and suggesting improvements, I have produced results which have been even more astonishing to me than to the people who have reaped the benefit, and I may state, with all due modesty, that by this means I have produced a result which is already noticeable to " the man in the street," in fact, three years of this method have achieved far more than thirty years of the old ineffective reliance upon legal methods only.

It is my claim that an efficient smoke inspector, given a free hand, can contribute considerably to economy in the cost of production :—

1. By reducing fuel costs.
2. By reducing the obstruction to sunlight, thereby increasing the mental and physical vigour of the whole population, resulting in more rapid and efficient production throughout.
3. By reducing the present terrible economic loss of sickness.

It is no idle boast to say that all this can be achieved for a town, a county, or a country, at a cost of a penny per head of population per annum.

Process Smoke.

The black smoke from the boiler does not, by any means, constitute the whole of the problem ; we still have the unavoidable smoke of process work to contend with.

The legislature have always been most careful to provide adequate exemptions for smoke of this description, and, I believe, wrongly so. It must be admitted that, in the present state of knowledge, the production of smoke is unavoidable in the course of certain manufactures, but I fail to see any good reason why this should be discharged to atmosphere with its solids unconsumed. Do we allow crude sewage, or poisonous dyes, to pollute our rivers just because the purification process is not a paying proposition ? Why, then, should we load our air with death-dealing soot ? I venture to say that if smoke were accompanied by an offensive odour, our forefathers would not have left us such a vile legacy.

I am fully aware of the fact that careful consideration in some cases would have to be given to the question of precautions against explosion ; but admitting this, and certain engineering difficulties, I see no reason why all process smoke should not be raised to ignition, supplied with air, and consumed in special boilers or furnaces, and so discharged to atmosphere as invisible gases instead of as solid carbon in suspension. The comparatively trifling cost of running such smoke-burning installations could be reckoned as the price of the increased health and energy of the employees of all classes, and I have no doubt that, indirectly, it would be a paying proposition, although this naturally would be a very difficult matter to prove.

In conclusion, I submit for discussion my opinion that the expenditure of a penny per annum per head of population on an efficient smoke inspection service throughout industrial Britain would, by reducing fuel costs, and increasing the supply of energy-

giving and germ-killing sunlight to the active population, lead to a much-needed decrease in the cost of production. Further, that it would be a gilt-edged investment for the nation in that the export trade would be stimulated, and that, under brighter skies, there would be far less irritation and dissatisfaction in the relations between capital and labour. In fact, I suggest a brighter and more cheerful atmosphere as of the greatest importance in the promotion of good feeling and as one of the cures for strikes.

The municipality would benefit by the reduction of the need for expensive sanatoria, and in reduced cleansing costs, whilst the individual would derive untold benefits by reduction of his household upkeep and lighting, and his sickness costs.

I would suggest a " Clean Sky " as a substitute for Acts of Parliament which give a return of 9d. for 4d.

Surely, if it is possible to abolish the wicked gloom of to-day, and by so doing to show an immense financial saving on balance, it is criminal to remain passive and indifferent. Would that we could foresee the comments of the generations to come on the sins of ommision perpetrated by " We of the Dark and Gloomy Age " !

Smoke Abatement and Boiler Room Economics in relation to the training of Steam Boiler Firemen

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PREFACE.

The chief aim of the writer in submitting this paper is to draw attention to the possibility of securing, by a series of lectures, an abatement in the smoke emitted from steam plant chimneys. Methods of training are usually either so haphazard, or intermittent, that many firemen are unconsciously perpetuating the errors of their forefathers.

Several excellent text books on steam plant practice have been published, but only in exceptional cases have they received the recognition they deserve by firemen, because to be sufficiently comprehensive or of practical utility a book must contain a large amount of advanced matter quite extraneous to daily routine work.

In arranging the proposed form and sequence of the lectures the writer has endeavoured, by avoiding the more theoretical aspects, to impress the student with the practical applicability

of the matters considered. It is assumed that, once the fireman is favourably impressed, and given reasonable opportunities for attending lectures, he will be encouraged to continue until eventually he will be able to appreciate the value of the more advanced literature. The elementary character of the lectures has accordingly been strictly adhered to, even at the risk of criticism.

It is not suggested that a series of lectures will equip an individual with all the qualifications required to ensure that his efforts will give comparatively smokeless combustion, since a certain amount of practical experience is essential before he can expect to be recognised as fully qualified. The lectures are accordingly intended to run concurrently with the daily avocation of those concerned with boiler management, so that the value or applicability of such matters as may be referred to can be ascertained under working conditions.

The prevalent impression that lectures must be given at the boiler front, and that actual demonstrations in firing are an indispensable part of the syllabus, is probably due to the fact that the many factors, other than personal dexterity—which factors, however, largely determine the efficiency of a fireman's efforts—have not hitherto been fully recognised by those concerned with smoke abatement. A quite cursory examination of the points referred to in the lectures, as set forth, will amply demonstrate the fact that dexterity in handling a shovel is a minor accomplishment compared with the many details requiring skilled control, if undue smoke emissions are to be avoided.

INTRODUCTION.

Fuels.

Over thirty years ago the writer was first concerned with the installation and working of a so-called smoke consuming device. The glowing press accounts and the statement made by interested persons that this marked the advent of a new era in which air pollution would soon be a matter of history, were, to say the least, somewhat over-optimistic, in view of the admitted necessity to-day for continued efforts. The experience gained with this appliance, and subsequent experience in the management of steam boilers generally, have confirmed the opinion of the writer, that, even if a boiler room be equipped with every available device to avoid excessive smoke, the individuality of the man in charge is by far the most important factor. Provided he is supplied with a reasonably suitable grade of coal, a careful and skilled fireman will make less smoke and more steam, for a given consumption of fuel, than a careless or unskilled fireman, even

when the latter has the advantage of a more expensive smoke abatement equipment.

It is estimated that over 45 per cent. of the coal consumed in this country is used in steam production, whilst that for domestic purposes is a little under 20 per cent. Domestic smoke, however, by reason of the low level at which it is discharged, and the greater percentage of carbonaceous, bituminous, and sulphurous vapours in it, compared with smoke of average density from steam plant chimneys, may be, and probably is, more obviously objectionable. These destructive but more or less combustible components of domestic smoke are mainly due to the comparatively low temperature at which the greater proportion of the coal is consumed, and their immediate contact with surrounding objects is responsible for a considerably higher proportion of the total damage due to atmospheric pollution, than that due to the consumption of the far greater percentage of coal used for steam raising. The damage due to the consumption of nearly 90 million tons of steam coal per year, compared with nearly 35 million tons for domestic purposes, however, is by no means negligible. Moreover, if proper means are adopted, more efficient combustion conditions may be attained in boiler furnaces than is possible with the average type domestic firegrate.

Coke.

Smoke from domestic chimneys would undoubtedly be greatly minimised if coke or some form of semi-coke were more generally used, but it is still uncertain whether there would be a corresponding reduction in the discharge of sulphurous fumes. The heating of a room by radiation from a firegrate, and the burning of a fuel to produce steam economically, are so dissimilar, however, that a little consideration will show the unsuitability of coke or even semi-coke for the latter purpose, unless existing boilers and furnaces are radically altered.

The evaporative capacity of a boiler depends directly on the liberation of a definite number of heat units in a given time, therefore, rapid oxidisation of the fuel is essential ; whereas the nearer a domestic fire can approximate to slow combustion conditions, the better will be the result financially from the householder's point of view. Reducing the calorific value of coal by high or low temperature methods must inevitably entail the consumption of a proportionately greater bulk of coked or semi-coked fuel for a given steam output.

Pulverised Coal.

The possibilities of securing complete combustion with suitable mixtures of air and gaseous or liquid fuels has encouraged engineers in their endeavours to burn powdered coal injected into

a furnace. The fact that many inferior grades of coal, by reason of their slag or clinker-producing characteristics, cannot be satisfactorily used on the normal firegrate, whereas they can readily be consumed in a pulverised condition, is also a strong inducement for continued efforts in this direction. It must be remembered, however, that pulverised coal is a manufactured commodity. The capital outlay involved in the pulverising equipment and the maintenance and supervision costs, must be debited against the ultimate cost of steam.

Hitherto there has been a reasonable uncertainty as to whether drying and pulverising, and the installation and maintenance of special refractory linings, do not more than counterbalance any economy due to the use of a cheaper fuel. Local circumstances, such as the absence or high cost of good coal, have led to the adoption of powdered fuel, in some instances, on the Continent ; but it is remarkable that, notwithstanding strenuous efforts to introduce this method in America, comparatively little progress has been made among steam users generally. Whilst admitting the possibility of utilising, by pulverising, the vast quantities of cheap low grade coal which are known to be available, yet the lower cost of better grade coals here, as compared with prices in many localities, considerably minimises any inducement to adopt this method in the British Isles.

When properly pulverised, coal can readily be burned smokelessly, but troubles due to the more or less intermittent discharge of coal dust or fine gritty particles have by no means been overcome. In view of current controversies respecting methods of pulverising, ultimate fineness of the fuel, methods of supplying the fuel to the furnace, most suitable form of burner, methods of removing slag and ashes from the furnace, fusibility or otherwise of refractory furnace linings, effect of slag or fluxes in a molten condition on metallic heating surfaces and so on, it will be evident that many problems connected with this system are still awaiting a definite solution. The firing of steam boilers with pulverised coal for general manufacturing purposes in this country is very exceptional, and cannot yet be said to have definitely emerged from its experimental stage.

Oil or Liquid Fuel.

The fairly rapid progress in the application of oil fuel in marine practice, raises the question why this method has not been more generally adopted for stationary and locomotive boiler purposes in this country. The proper selection of suitable crude oils and their ultimate combustion for steam production purposes are not nearly so difficult, as with most other forms of fuel, nor do they involve the use of elaborate and controversial

devices. Ideal conditions of combustion are easily attainable with suitable mixtures of oil and air, experience having shown that this method of firing is past the experimental stage and that, under proper conditions, it is not nearly so liable to pollute the atmosphere as the more usual methods of firing with coal.

The conditions under which steam is produced for marine and for normal manufacturing purposes on land, however, are widely different. With coal firing a large steamship may have a boiler staff of about 300 firemen and trimmers, but with oil firing only 80 or less are needed, this reduction also applying proportionately to smaller steamships. Bunker space is an important item in seagoing vessels, the space necessary for oil fuel being very considerably less, and more conveniently located, than for coal. The annoyance with coal dust, as when coaling, is eliminated, in addition to a reduction in the time and cost of fuelling. These and other reasons, such as the possibility of obtaining supplies in countries where oil is little more costly than coal, are factors which have no relation to stationary or locomotive boiler practice here. A comparison of the approximate price and heat value of oil, as compared with good average steam coal in this country, will indicate the improbability of oil successfully competing with coal for steam production purposes generally, unless there be a substantial reduction in the price of the former.

Fuel	Cost per Ton.	Heat Value in B.Th.U.	Relative Heat Value.
Coal	21/6 ...	12,000 ...	1·0
Oil	75/- ...	18,000 ...	1·5

Notwithstanding its higher calorific value and lesser ash content, the heat content of fuel oil is actually more costly than coal, and a considerable proportion of this difference in first cost is reflected in the ultimate cost of the steam produced. Since the supply of fuel oil is comparatively restricted, and wasteful loss of by-products occurs as with coal, little relief from air pollution can be expected in this direction.

Undue optimism regarding new methods has already been referred to, and it will now be evident that the preceding remarks respecting alternative fuels point to the necessity for cautious and disinterested research under such actual working conditions as will render the data obtained of undoubted commercial value generally. The fairly prevalent impression that there is the possibility of a considerable relief from air pollution troubles, if steam users could be induced to adopt special fuels, has probably led to a feeling that steam plant owners may be more or less indifferent to purer atmospheric conditions. For manufacturing purposes, cheap power is so essential that steam users cannot reasonably be blamed for a reluctance to adopt more or less

experimental methods. When the previously mentioned objections to the use of coke and powdered coal have been overcome, their general use will become almost inevitable. In the meantime, the numerous cases of legal proceedings following repeated warnings by the health authorities that certain chimneys are violating admittedly lenient smoke ordinances, point to the fact that the time for securing some improvement in atmospheric conditions is here and now, hence the following suggestions in respect to lectures suitable for firemen, engineers-in-charge, and others who may be concerned in the production of steam by the combustion of coal.

Modern tendencies are clearly in the direction of large power stations, which may be located at some convenient centre near collieries or adjacent to localities wherein there is an abundant supply of gaseous fuel from blast furnaces, coke ovens, metallurgical furnaces, or destructor installations. Super power stations may provide opportunities for research on and utilisation of alternative fuels which are quite unsuitable for normal steam plants to-day. Even with these isolated high-power stations, such smoke as may be discharged from the chimneys will obviously be carried by air currents over the surrounding districts, and it is reasonable to suggest that, notwithstanding the comparatively high altitude of emission, a more or less impenetrable screen of smoke may obstruct the free passage of light rays, which are well known to to be essential to the well-being of a community.

THE TRAINING OF STEAM BOILER FIREMEN.

In discussing air pollution generally, and smoke abatement in particular, cognizance should always be taken of the necessity for expert knowledge of or some familiarity with the different processes involved in the manufacture of any commodity that may be more or less dependent upon the combustion of a fuel for its successful production. Even among experts in the steel and pottery industries for example, acute differences of opinion exist as to the ultimate effect on price and quality of the finished product, if there be undue interference with established practice in the burning of fuels during certain stages of manufacture.

Smoke Abatement in relation to Steam Plant Practice.

So far as the production of steam is concerned, however, there is a growing opinion that unduly heavy emissions of smoke are not only more or less avoidable, but, also, that such generally mean uneconomical furnace conditions. On the other hand, a perfectly clean chimney is not always evidence that steam is being produced economically, since invisible but combustible gases may be polluting the atmosphere. With some grades of coal

and conditions of draught, the carbon particles of which smoke is mainly comprised can be so diluted as to give the impression of a reasonably clean chimney, notwithstanding the fact that fuel losses are resulting from improper control. The excess air may be admitted through the boiler furnaces, faulty damper gear, or faulty brickwork.

Fuel is expensive, but air is free and abundant, hence the neglect of reasonable precautions, whereby losses of heat may be restricted by proper attention. Although an excessive discharge of smoke usually indicates uneconomical furnace conditions, a cursory inspection of the chimney top does not mean that all is well.

Examples of Different Forms of Atmospheric Pollution by Steam Plant Chimneys.

Many instances could be quoted to show that losses of heat and air pollution by steam plant chimneys are generally due to incomplete combustion, but the following examples will indicate potential causes and possible remedies :—

1. As a result of attending lectures, special endeavours were made to prevent infiltration of air through damper slides, flue brickwork and so on, but it was then found that the formerly reasonably clean chimney gave excessive smoke. By adjusting the draught and thickness of firebed, the nuisance was entirely abated and a saving effected in the coal bill of 20 per cent.

2. Undue emissions of smoke and low evaporative capacity ($3\frac{1}{2}$ lbs. per lb. coal) were put down to moisture percolating into flues, but a lining of cement resulted in little, if any, improvement. By adjusting the dampers in accordance with the rate of combustion, the draught was reduced by about 50 per cent. over the greater part of the working day. The improved conditions of combustion gave an increase of evaporative capacity from the previous $3\frac{1}{2}$ to $5\frac{1}{2}$ lbs. of water.

   Note.—These boilers worked under low pressure conditions with no economisers or feed water heaters.

3. The chain of a single damper had been shortened by breakage, but the damage had not been reported, so that, although the damper was still adjusted in accordance with a mark on the boiler front, as previously found to be the best position, the damper opening was larger. The resulting increase in the coal consumption was avoided by repairing the chain.

4. Chimney repairers complained of irritating fumes discharged by an apparently clean chimney, whereas they could work

continuously on a neighbouring and notoriously smoky shaft. In this case colourless but poisonous gases were probably being discharged, the detrimental components undoubtedly containing an undue percentage of carbon monoxide or sulphur dioxide or both. Incomplete combustion was obviously taking place in the boiler furnaces, and probably no greater efficiency was being obtained than in the boilers connected to the smoky chimney.

Many other examples of differing conditions and the resultant effects could be quoted, but the foregoing will doubtless indicate the impracticability of formulating a rigid set of rules for all conditions of service. Fortunately, efficient conditions in the boiler furnaces will also reduce to a reasonable minimum the discharge of smoke, or other obnoxious products of imperfect combustion.

Manipulative Training in the Boiler Room.

It has been suggested that good results must inevitably accrue from the employment of experts for visiting the different boiler plants, with a view to demonstrating under actual working conditions the most suitable methods for attaining economical conditions, and, indeed, this procedure has been adopted to a limited extent in more than one country abroad. Although this may be preferable to the haphazard method of choosing a fireman mainly by reason of his physical qualifications, it is not necessarily the best or even the only means whereby the best results may be obtained. Prevailing local winds and the location of a boiler plant have a direct bearing upon the intensity of the draught, and this, together with the grade of fuel available or rate of firing required, determine whether sprinkling, side, coking, or a combination of these methods is the best, not to mention the effects of grate area, firebed thickness, and so on.

A fireman merely instructed in the art of manipulating the firing shovel and draught under certain fixed conditions, may be quite inefficient if such conditions be varied. Boiler firemen cannot be regarded as fixed stock, and they do insist upon their right to change their place of employment. The transference of services elsewhere would accordingly entail the disregard of a considerable amount of previous tuition, and would necessitate the use of greater faculties of discernment than has hitherto been expected of the normal type of attendant.

Alternative to Manipulative Instruction.

Hitherto, apparently there has been a lack of desire on the part of boiler firemen, generally, to take advantage of such training facilities as local education authorities have shown a willingness to provide. More than ten years' experience of courses of lectures

on boiler management and smoke abatement have shown that the majority attending is mainly comprised of engineers-in-charge, younger members of boiler insurance companies' staffs, foremen and craftsmen in boiler and general engineering works, with a minority of from fifteen to twenty per cent. students who actually handle the firing shovel, or operate mechanical stokers.

Lack of enthusiasm for lectures is probably due in the first instance to a difficulty in attending, and secondly to previous inability to attend lectures in a technical institution. The latter reason may undoubtedly be conducive to a personal suspicion that not only will the lectures be too scientific but, also, that they must necessarily be more or less inapplicable to the conditions under which a given plant may have to be operated. This assumption may be based upon the impression that the lecturer is unfamiliar with difficulties arising from changes in the grade of coal available, and maintenance troubles generally. The importance of avoiding the more academic aspects and dealing with all matters appertaining to smoke abatement from a practical point of view will accordingly be obvious, the subsequent recognition of the usefulness of the lectures then becoming the concern of those whose interests are materially affected.

Without minimising the advantages that must accrue in smoke abatement and steam plant economy from attendance at a suitable lecture course, more encouragement and accompanying skilled guidance will be extended to firemen when the responsible officials are sufficiently alert to the possibilities of the skilled control of furnace conditions. Instances have occurred in which a fireman has actually been discouraged by his immediate but ill-informed superior when endeavouring to ascertain how smoke emissions could best be avoided, because, in the preliminary stages at least, such endeavours must necessarily be, more or less, on trial and error lines. Whether actually handling the firing shovel or not, all concerned with the purchase and use of steam coal should be conversant with modern practice in regard to smoke abatement. If considered necessary, and provided the number of intending students was satisfactory, it should not be difficult to arrange for lectures for officials on one evening per week, and for the actual firemen or spare firemen on a different evening.

Applicability of Technical Instruction to Boiler Room Conditions.

As distinct from the more empirical manipulative training, lectures should be progressive from a very elementary beginning, and should deal at different stages with principles which are applicable to all kinds of boilers, grades of fuel and intensity

of draught. Natural resources such as coal and air should accordingly have first consideration, in order to indicate the reasons for the very considerable differences in the behaviour of different grades of coal during ignition and subsequent combustion. The large preponderance of comparatively useless nitrogen which must be heated to the temperature of the products of combustion, when air is admitted in excessive quantities, should have consideration with a view to showing how heat losses and the accompanying low furnace temperatures so conducive to heavy smoke emissions are unavoidable with inefficient methods of draught control.

Suggested Form and Progressive Sequence of Lectures.

The progressive stages of a course of lectures are easily and clearly definable, the following being a brief and sketchy outline.

(1) Coal, its Formation, Composition and Classification.

It is sometimes stated that a ton of a given grade of coal, whether it be slack, nuts or cobbles, possesses a known and definite calorific value, but such a statement is of little use to a fireman since the furnace conditions which are suitable for efficiently burning a high grade coal may be quite different from those suitable for the avoidance of heavy smoke emissions with a lower grade of coal. The development of a bed or seam of coal from its vegetable origin to its final anthracite stage should accordingly have first consideration, to show the possibility of having to deal with coal in one or other of the different stages of development, and the consequent differences in volume of the volatile elements released during ignition, which are mainly responsible for undue smoke emissions with unsuitable furnace conditions.

(2) Boiler Draught, its Production and Control.

This stage should include a description of the methods adopted in producing natural, forced and induced draught, and the advantages and disabilities of the different systems should have consideration. Some actual examples will indicate the importance and scope of this stage of study.

(*a*) A battery of boilers gave a low steam output, but increasing the rate of firing with the coal available resulted in heavy emissions of black smoke. The main flue was enlarged at a cost of well over £1000, but little draught improvement was obtained. An induced draught fan, installed at a comparatively small cost, gave the desired rate of evaporation without undue smoke emission.

(*b*) Early in the war, a battery of boilers was worked with induced draught, the chimney being the shell of an old Lancashire boiler. This shows the independence of mechanical draught in regard to chimney effect.

(*c*) In Manchester, induced draught applied to a chimney built for a 200 h.p. boiler enabled a subsequent installation of 1000 h.p. boilers to be worked without undue smoke.

Under most conditions, natural draught is found satisfactory and economical, while, on the other hand, increased demands for power and the grade of fuel available may be such that mechanical draught, either forced or induced, will be found most satisfactory. Mere volume, however, is not the only consideration in draught control, since the grade of coal and draught available almost invariably determine the proper thickness of firebed, and hence, any variation of the latter entails a corresponding adjustment of draught to obtain the best results. In some cases of insufficient natural draught, it may even be possible to accelerate combustion and thus reduce smoke by a reduction of grate area, while, on the other hand, with ample draught and fine slack or dust, increased grate area and a thinner fire may be most advantageous.

Skilled control of firebed thickness, according to grade of coal and draught adjusted to suit, are most important factors in efficient furnace conditions. In this connection, one example will probably indicate the possibility of success when skill is properly applied. A fireman working two boilers in a basement could not see the chimney top and could not therefore control his fire, heavy smoke being evolved, resulting in fines on several occasions. As a result of attending lectures, however, he had realised the possibility of controlling the draught according to thickness of firebed and grade of coal in use. By a proper observance of the effect of his endeavours on furnace conditions and by firing accordingly, the chimney was now reasonably clean, and he was complimented by the Smoke Inspector concerned on the very marked improvement.

The application of draught gauges or draught regulators and so on, as sometimes required to maintain continuously the best furnace conditions, should also have attention at this stage, and a description of some of the many different appliances for delivering air at the front or rear, or both at the front and rear of the firegrate, will also be helpful, as demonstrating the importance of the subject. The fact that some appliances are failures under some conditions while, in other instances, they are successful, indicates the need for judicious control in all cases. Improper control or unsuitable conditions may render many of these appliances not only useless, but actually detrimental.

The chilling effect of cold excess air at the front or back of the firegrate may prevent ignition of the volatile hydrocarbons, etc., and the ultimate result is either a loss of heat or heavy smoke emissions, or both. Moreover, the volume of air required immediately after firing is usually considerably different in amount from that required when the fuel is incandescent, and hence, unless the air supply is controlled to suit the different rates of ignition with either free or slow burning coals, there is an inevitable loss of efficiency. With heavy intermittent firing, these difficulties are correspondingly accentuated.

(3) The Combustion of Coal on a Boiler Firegrate.

It will now be possible to discuss the physical phases of combustion with a view to subsequent discussions on methods of firing, flue gas analysis, and so on. Large size scale diagrams, showing the approximate average composition of steam coal, and the large preponderance of wasteful nitrogen in the atmosphere will be useful. The amount of fixed or volatile carbon that may be available per pound of coal consumed, and the comparatively small percentage of oxygen in the necessarily large volume of air passing through and over the firegrate, may also be emphasised before describing the actual combustion of coal.

In order that the description of chemical reactions involved during combustion may be removed as far as possible from its more theoretical or chemical aspects, graphs or charts showing the combination of oxygen with the carbon in the coal, and the temperatures resulting from efficient and inefficient oxidisation, are recommended. It can be shown how, under suitable conditions of temperature and draught, two parts oxygen combine with one part carbon, to form carbon dioxide, CO_2. This gas, being the product of perfect combustion, is incombustible, and hence, a reasonable percentage of the twenty-one possible, indicates efficient furnace conditions, providing no carbon monoxide be present. The comparatively low ignition temperature of coal compared with that of efficient combustion should also be referred to, showing how combustion may occur at a much lower temperature than that at which CO_2 is produced, or, in other words, that the products of combustion may contain an undue percentage of CO, in which case one part oxygen only has combined with each part of carbon, this combination producing a colourless and poisonous, but combustible gas, carbon monoxide.

The means to be adopted to ensure the conversion of such CO as may be produced to CO_2 may then be discussed to show the possibility of losing, with improper furnace conditions, nearly two-thirds of the fuel's heating value. On these lines, the discussion must involve suitable references to furnace temperatures,

thus showing that high temperatures are not only conducive to economy, but also to reasonably clean chimneys. Success in attaining these high temperatures is directly affected by the firing, draught control, thickness and cleanliness of firebed, condition and area of firegrate, and other relative circumstances. The discussion therefore leads up to a consideration of the different methods of firing.

(4) Hand Firing Methods.

Grade of coal, intensity of draught, evaporation required per square foot of grate or heating surface, methods of cleaning fires, control of feed water, etc., are, generally, the principal factors requiring attention when considering different methods of firing. Whichever method is adopted, the object should always be the same, *i.e.*, the continuous maintenance of uniformly high temperatures with a firebed of proper form and thickness without holes or dead patches.

The sprinkling of the coal over the whole firebed area is probably the method most generally adopted with slack or fine nuts, and this procedure is undoubtedly satisfactory if a clean thick bed of incandescent fuel is maintained against the bridge wall in Lancashire and Cornish boilers. With heavy smoking, slow burning, or very light and friable coals, side firing or a combination of side with a little front firing may often be found the most advantageous. With this method, the radiant heat from the incandescent fuel on the non-fired side of the grate is used in maintaining the furnace temperature above the ignition point of carbon monoxide, hydrocarbons and so on, and, by compelling the gases to pass through a zone of very high temperature at the bridge end, the combustible gases are consumed before they pass to lower temperature conditions.

Front firing calls for a high degree of skill and familiarity with the characteristics of the coal used, if smoke is to be avoided. The fuel is first coked on the front portion of the grate, thus compelling the products of ignition to pass over the incandescent fuel on the rear portion. It is difficult, however, to determine the condition of the coking fuel, and, if the front portion be disturbed too early when pushing back the fuel, heavy volumes of smoke and other combustible gases will be released from the inner mass of the coking coal, and will most probably pass unconsumed to the chimney. Also, with many grades of bituminous coal, the coking process may be seriously retarded or inefficiently carried out by reason of caking or clinkering characteristics. If the fuel be overcoked, there is a liability to the rear portions of the grate becoming bare, or, at least, covered with dead patches surrounded by intervening holes, through which considerable excess air can pass.

Unless the coal is very small, therefore, side firing with a little front firing will generally be found the most satisfactory, the incandescent front portion thus being available for subsequent distribution over the whole of the grate, when a levelling up of the firebed becomes necessary. Unless the coal be of the better grades and of reasonable size, over-heavy side firing may even be conducive to excessive smoke, and, consequently, notwithstanding the inevitable heat losses when the furnace doors are opened, the little and often method will generally be found to give the best results. With small heavy smoking grades of coal, the firing shovels should not be too large, otherwise there is always the liability to deliver an undue thickness of green coal against the comparatively cool heating surfaces on each side of the grates of internally-fired boilers, or unduly thick patches of small coal in the furnaces for externally-fired boilers. It will also be evident that, unless the grate be of such a height in the furnace that there is ample space in which the gases may mix with the oxygen, premature chilling effects against the heating surfaces may occur, with consequent incomplete combustion.

Side firing entails the placing of the green coal on one side of each grate alternately, and then following on with the other side of the grate, beginning, of course, with the first boiler fired. With three or more boilers this procedure entails almost constant movement on the part of the fireman, and, if not overdone, the little and often system will be conducive to uniformly high furnace temperatures, while, at the same time, the proper draught regulation will be rendered less intricate than with heavy intermittent methods of firing. The following incident is pertinent :—

> A millowner was showing a friend over his power plant, and, on entering the boiler room, the friend noticed the fireman sleeping in a dark but cosy corner. " Do you allow that sort of thing ? " he asked, and the owner, after noting the pressure gauge, replied, " The pressure is quite correct, so please don't waken him, because, if you do, he will immediately begin to throw coal into the furnaces."

Obviously, the need for constant attention to secure the best results was not fully appreciated at that mill.

The proper burning down of the fire, cleaning-out operations, and the subsequent efficient rebuilding of the firebed in the shortest time should also have consideration. Rebuilding before normal incandescence has been attained, is probably one of the most frequent causes of heavy smoke emissions, and, if unskilfully carried out, the cleaning operations may result in very appreciable losses due to the withdrawal of partly burned fuel. The need for constant attention and the unavoidable heat losses when firing, slicing or cleaning out under hand-firing conditions,

are practically eliminated with mechanical stoking, and since the operations of the different forms of mechanism used for this purpose are comparable to the efforts of a highly skilled fireman, the principles of the different systems and the ultimate effects on combustion are worth consideration.

(5) Mechanical Methods of Stoking.

Mechanical stokers may be divided into two distinct types, *viz.*, the overfeed or spreading, and the front feed or the underfeed coking types. The success of the first type depends mainly upon the proper adjustment and maintenance of the throwing mechanism, since, if there be any neglect in this respect, imperfect fuel distribution occurs, and the ultimate results may be quite as bad as those obtained through the efforts of the most inefficient or careless manual stoker. Properly adjusted, the mechanical throwing shovel delivers the coal alternately on different portions of the grate, *i.e.*, if the grate be 6 feet long, the throw may be adjusted to deliver regularly small quantities of fuel to each linear 18 inches of grate, thus avoiding the deposition of green coal on fuel which has not had time to become incandescent, the result being the continuous maintenance of a uniformly high temperature. Coal dust is not a lubricant, and hence it is essential that those parts of the mechanism liable to fairly rapid wear should be renewed at proper intervals, if reasonably satisfactory results are to be expected.

The front feed coking stoker is provided with moving grate bars which are pushed bodily forward and are then withdrawn in alternate pairs or, as in another design, the bars may be made up of short links in the form of a chain grate, which is actuated by suitable drums or pulleys. When maintained in proper order, and with suitable coal and proper adjustment of the feed, coking stokers are not only smokeless, but also reduce the liability to the discharge of grit with the flue gases to a minimum. The moving bar grate receives the coal from the hopper on a coking plate, and with the chain grate the coal is received directly on the grate at the front of the furnace. The combustible volatile elements which are mainly produced at the comparatively low ignition temperatures thus pass over the incandescent fuel on the rear portion of the grate. The moving bars of both the sprinkling and coking types and the chain grate stoker finally deposit the ash and clinker at the rear end of the grate, from whence they can be withdrawn as required without opening the furnace doors.

By reason of mechanical and adjustment limitations, it is quite if not more essential with machine than with hand stoking, to use only such grades of coal as are suitable for the draught

available, and rate of combustion required. The rate of the coal feed and travel of grate are independently adjustable, and, consequently, mechanical stoker makers may endeavour to minimise the difficulty of keeping the grate properly covered with an even firebed thickness over the whole area, and at the same time avoid the deposition of partly consumed fuel in the ashpit. Nevertheless, it is impossible for a mechanical contrivance to automatically vary its operations as and when required, so rapidly and intelligently as a skilled fireman. In cases of wide variations in the characteristics of the coal, or of the steam demands, the utility of mechanical methods will depend on suitable supervision and manipulation. Moreover, unless the travel of the grate be adjusted to suit the rate of combustion, not only is there the liability to losses due to partly consumed combustible, but if the travel be too slow, the rear portion of the grate will become covered with dead refuse, and so permit the influx of huge volumes of cold air.

Under suitable conditions and particularly if the boiler be worked at or over its full rated capacity, mechanical stoking will almost invariably give better results than hand-firing methods. The supply of fuel to the furnaces in such small and regular quantities as would be impossible with hand firing, and the consequent uniformly high temperatures, also permit the use of a cheaper coal without excessive smoke than is permissible with the fallible manual stoker. The opening of furnace doors, with the inrush of large volumes of cold air when hand firing or cleaning, is also obviated, and this immunity from periodic chilling effects is particularly beneficial when superheaters and economisers are installed. High temperatures are always conducive to the combustion of the semi-combustible impurities which are present in all grades of bituminous coal. The partial combustion of such impurities as would be liable at the lower temperatures to form clinker and dross, not only improves the combustion, but the higher temperatures also prevent the escape of gaseous and smoky components of the fuel, in addition to minimising the unavoidable fuel and heat losses which occur every time the fires are hand cleaned.

Underfeed stokers also utilise the coking process, in that the fuel is first ignited below the hottest zone of combustion, the combustible volatile gases thus passing through a temperature well above that at which they became converted to carbon dioxide. A suitable rate of feed and proper draught adjustment are quite as essential with this as with other coking types and, unless properly controlled, difficulty may be experienced in retaining the coking process on the proper portion of the grate for front fired stokers, or at a proper depth in the fuel, as it rises from the underfeed stoker trough.

The operations of these different forms of mechanical stokers are well known, and are referred to mainly in order that the student may realise the great similarity of the principles governing the best methods of hand firing and those applied through the operations of a mechanical contrivance, emphasising at the same time the necessity for constant and skilled attention. Lack of attention and consequent unsatisfactory results have occasionally caused a strong prejudice against all forms of mechanical stokers. This prejudice has sometimes led to the scrapping of a complete outfit, although the faults were really due to inefficient supervision and maintenance. Stoker makers are not entirely blameless in this regard since it was formerly common practice to assert that little or no skilled attention was required. Moreover, proper maintenance of the mechanism entails much more attention on the part of the engineer-in-charge than is necessary when skilled manual stokers are employed, and hence some remuneration for these additional duties will generally be more than fully covered by the ultimate saving in coal, not to mention a corresponding freedom from smoke emission.

The economy due to mechanical contrivances, whether for draught production, stoking or ash conveyance, is mainly determined by the location and capacity of a plant. The labour involved in working one, two or even three boilers, whether hand-fired or fitted with stokers and hand-filled hoppers, will be comparatively much greater for a given steam output than with a battery of, say, eight or more boilers with mechanical equipment for handling the coal and ashes. The size of plants varies from that of a small single boiler and engine, controlled by one man who is engineer-in-charge, fireman and greaser combined, to the more extensive plants, which may be controlled by numerous grades of boiler room attendants, working under the direction of one or more steam plant experts, or so-called combustion engineers. In all cases, however, some method of ascertaining the completeness or otherwise of combustion will be advantageous, and the previous discussions have accordingly been progressively arranged with a view to leading up, in a simple manner, to a consideration of the methods adopted to ascertain the percentages of certain components in the flue gases.

(6) Flue Gas Analysis.

References were made when considering combustion to the fact that the flue gases contain greater or lesser percentages of CO_2, free oxygen and CO, according to temperature conditions, and, since CO_2 is the product of perfect oxidisation, a determination of the quantity present must necessarily give some indication of the completeness, or otherwise of combustion. A comparatively small percentage of CO in the flue gases is definite indication

of imperfect and uneconomical combustion, and hence, it may also be found advantageous to test for this gas from time to time. The presence of CO is usually due to low furnace temperature, and this latter may result from an insufficiency of oxygen under poor draught conditions or from a firebed too thick or clinkered. On the other hand, low temperature may be due to cooling effects of excess air, in which case an undue percentage of free oxygen will be present in the flue gases.

A proper analysis of the flue gases, therefore, may occasionally involve the determination of the relative percentages of CO_2, CO and O, in which case a portable apparatus such as the Orsat may be used. The principle upon which the Orsat analysis is based is practically similar to that employed in the more usual automatic recorders, and hence, a reference to its construction and manipulation will serve as an introduction to a consideration of some of the different forms of CO_2 recorders in everyday use.

The Orsat consists essentially of three flasks or pippettes which contain respectively the following solutions :—Caustic potash, pyrogallic acid and cuprous chloride. A measured volume of flue gas (usually 100 c.c.) is induced by an aspirator or other means to enter the apparatus, and is then forced to make contact with the caustic solution, which absorbs CO_2. Any reduction of volume, after contact with the solution, is accordingly a measure of the CO_2 in the sample. The remainder of the sample is passed consecutively into the flasks containing pyrogallic acid and cuprous chloride, the former absorbing any free oxygen, and the latter carbon monoxide. These tests cannot be carried out in the time usually at the disposal of a fireman, and, as a consequence, they are generally made by the engineer-in-charge or, if the plant is extensive, by a special attendant.

To be of routine service to the fireman, some form of automatic device is essential, and there are now many suitable CO_2 recorders. Carbon monoxide is usually present in such small quantities that an automatic apparatus for testing for this gas must be necessarily exceedingly delicate to attain the requisite accuracy. Fortunately, it will generally be found that when the draught, thickness and form of firebed and furnace temperature are suitable for the production of a reasonable percentage of CO_2, there will not be more than a trace of CO in the flue gases.

Notwithstanding its limitations, the CO_2 indicator or recorder may be regarded as a reliable aid in attaining such furnace temperatures as are essential to complete the combustion of both the visible hydrocarbons—smoke—and the more or less invisible, poisonous and combustible products of imperfect combustion, which, from the air pollution point of view, are certainly as bad

as, if not worse than smoke. Difficulties of maintenance and occasional inaccurate or unreliable indications with some types have damped the enthusiasm of many owners and operators for these aids to boiler room economy, but there are many makers of repute who are only too glad to give substantial guarantees in this respect.

The following incident will indicate that occasionally there may be reason for some hesitancy in accepting the assurance of interested persons. An engineer-in-charge was not satisfied that his indicator was reliable, as it was consistently showing 13 per cent. although the flue gas temperatures were obviously below normal and smoke emissions were giving trouble. The makers were communicated with and the representative who called, after some little readjustment, assured the engineer that the indications were quite O.K. In the absence of any improvement in the conditions, however, the engineer eventually called in an expert who tested the instrument against an Orsat. It was then found that 13 per cent. as shown by the indicator was equal to 3 per cent. as determined by the Orsat. In contra to this, the writer has had under observation for many years two reputable CO_2 recorders, which have been tested on many occasions against different Orsat instruments, and at no time has there been more than from half to one per cent. difference in the results.

Proper supervision and maintenance are essential to ensure the reliable assistance of recorders, and hence the time available on the part of those immediately concerned will determine the advisability of continuous or occasional testing for CO_2. With a given grade of coal and intensity of draught, firemen may so adapt their methods when the CO_2 recorder is working that a satisfactory efficiency is afterwards continuously maintained, even when the indications of a CO_2 recorder are only available occasionally. The regular assembling and analyses of continuous records from the many different aids to boiler room economy that are now available, requires more time than is at the disposal of most boiler room attendants or engineers-in-charge. Unless the plant be large enough to merit the full services of one or more employees for this purpose, occasional or even snap tests for CO_2, flue gas and feed water temperatures, and so on, may be found, not only the most that can be done in the time available, but also quite satisfactory from the fuel economy and smoke abatement points of view, providing the grade of coal is not liable to recurring or intermittent changes, and the conditions of draught are fairly constant. In other words, the cost of compiling continuous records may sometimes be found less economical than occasional tests, or intelligent snap observations, as and when convenient.

In the entire absence of facilities or time for testing, it is worth considering whether arrangements could not be made by individual owners for the periodical visit of a qualified inspector, to carry out tests for determining the efficiency of combustion, tests for flue leakages, and to report on condition of brickwork and dampers, etc. Boilers and other vessels subjected to internal pressure are usually inspected regularly, to ensure safety and reasonably efficient maintenance, whereas the conditions governing the consumption of an expensive fuel may be, and often are almost completely neglected. Insurance companies would be doubtless quite ready to assist in such an arrangement, and the results of the tests would thus be available for guidance in firing the boilers. If CO_2 recorders or indicators were already installed, the tests would act as a check against the instruments, and as a result of the educational value of such tests, the fireman could be expected to take more than a cursory interest in matters of fuel economy, and its intimate relative smoke abatement. Many firemen, of course, are keenly alive to the possibilities of trouble due to excessive smoke emissions, and in the absence of proper facilities for guidance it is not surprising that improper methods are often resorted to, when endeavouring to avoid the attentions of the smoke inspector. The indications of the pressure gauge assist in reducing wasteful blowing-off at the safety valve to a minimum, and the visibility of the water in the gauge glasses is conducive to the maintenance of the water level at a uniform and proper height in the boiler, but facilities for guidance in firing the boiler are often conspicuous by their absence.

Alternatively, it may be found advantageous to grant additional remuneration in the form of a bonus for a consistently high percentage of CO_2, in which case a continuous record would be essential. Under some conditions and with certain grades of coal, however, it may be possible to obtain a satisfactory CO_2 percentage with the air supply so restricted that there may be an undue percentage of CO in the flue gases, in which case the advantage of a periodical and independent test is obvious. The writer knows of one instance in which the firing of one of the boilers, in a battery of six, was so controlled that ample CO_2 was present in the gases near the point in the main flue from whence samples were supplied to the CO_2 recorder, notwithstanding the fact, eventually established, that there was also an undue percentage of CO, and the remainder of the boilers were inefficiently operated. In this instance the bonus was discontinued, but such improper methods could readily have been overcome by properly locating the ends of the gas sampling tubes in the flues, and passing the pipe connections to the CO_2 recorder through a common junction box containing cocks, whereby any specific boiler could be placed under test. The key for this box would be retained by the engineer or other

responsible official, so that the gases under analysis could be obtained from any particular flue at will, and by thus secretly switching over from boiler to boiler occasionally, the firemen would be unable to ascertain which flue was in communication with the CO_2 recorder.

Size of steam plant, conditions of service and other governing factors will determine the most suitable methods of ascertaining boiler furnace and flue conditions, but, no matter how small the plant may be, the numerous forms of recording or indicating appliances, ranging from the perfectly simple apparatus for testing for CO_2 only, or simple and practically automatic collectors, whereby gas samples may be obtained direct from the flues and tested elsewhere, allow for no reasonable excuse in the matter of insufficient data upon which to base the most suitable methods of control. The determination of the CO_2 is a direct measure of the volume of unnecessary air which has been wastefully heated to the temperature of the flue gases. When the proper amount of air is admitted, the furnace and flue gas temperatures may be higher, with a corresponding reduction in the liability to heavy smoke emissions, and a minimum fuel loss, as compared with a considerably lower flue gas temperature, when excess air is admitted. In the former case, the higher temperatures are available for feed water heating and draught production, whereas, in the latter case, and notwithstanding the lower exit temperature, the total heat loss may be considerably augmented, by reason of the greater number of heat units contained in the larger volume of air passing to the chimney.

Shape and condition of firebars, area of firegrate, height of grate in furnace, use or misuse of steam jets, grade of coal, control of feed-water supplies and height of water in boiler, protection of heat radiating surfaces, and numerous other factors, have each their bearing on the ultimate results, and hence, it is reasonable to suggest that until the many different points have each had due consideration, any endeavour to abate a smoke nuisance, or to prevent losses of heat, has been incomplete. It is not suggested that the highest efficiency must necessarily involve the purchase of the most complex, or expensive aids to boiler room economy, since it is quite easy to appreciate that the first cost and maintenance of a too elaborate equipment may more than counterbalance any gain due to fuel economy. Within reasonable limits, however, it will generally be found that the judicious installation of draught gauges, and suitable forms of CO_2 recorder or indicator, according to the steam-producing capacity of the plant, will be conducive to the economical combustion of either high or low grade fuel, and with satisfactory results from the air pollution point of view.

With regard to the maintenance of boilers and the essential adjuncts, neglect in this respect may be indirectly the cause of excessive smoke and consequent pollution of the atmosphere. Dirty internal or external boiler heating surfaces, or economiser tubes, may entail undue forcing of the fires to produce the steam required. The amount of water evaporated per pound of coal consumed is a simple measure of efficiency, and hence, the continuous records of a feed water meter are extremely helpful indications of either proper attention, or neglect, in the maintenance of a steam-producing plant. The zone of combustion in a boiler furnace, which gives the best results, is immediately contiguous to the zone of excess air on the one hand, and to the zone of insufficient air on the other hand. The latter zone is usually indicated by excessive smoke emissions at the chimney top, and is accordingly more or less obvious, but the former zone, by reason of the semi-transparency of escaping combustible gases, is not nearly so obvious, hence the importance of means whereby the condition of boilers, intensity of draught, and efficiency of combustion may readily be ascertained at all times.

The number and variety of the many boiler room details preclude a complete reference in this necessarily brief résumé of a suggested sequence of lectures, but it will now be evident that the latter can be arranged in such a manner that they will have a direct bearing on the practical everyday work of a boiler fireman, and the intimate relationship of boiler room economies and air pollution. In the past, lectures on " The Management of Stationary Steam Boilers and Smoke Abatement," at the Manchester Municipal College of Technology, have been arranged as (1) a short summer course, without a final examination, and (2) a longer winter session, with a terminal examination, at which the successful candidates may obtain a certificate of proficiency. The short summer course is mainly intended for such boiler and engine room attendants, or others who may be concerned with the running of a steam plant, as may not desire to sit for examination. During the longer winter course the students are expected to obtain a certain percentage of the number of possible marks for home exercises, and to sit at the terminal examination. The latter is essentially practical in character, and, as will be seen from the appended questions as set for the 1923-4 sessional examination, the preceding lectures and home exercises must necessarily have been essentially practical in character, combined with an almost entire absence of such more or less academic or theoretical intricacies as would be foreign to the everyday work of a fireman :—

STATIONARY STEAM BOILERS AND SMOKE ABATEMENT.

Thursday, 22nd May, 1924. 7 to 10 p.m.

Note.—The value of each question is indicated at the end.

Candidates are required to attempt not more than ten questions.

Questions.

1.—Describe the origin and subsequent development of a bed or seam of coal, and explain the differences in the characteristics of the various grades of steam coal now available for steam raising purposes. (20)

2.—Describe the process of coal combustion on a boiler firegrate, and explain the methods of firing and draught control whereby an efficient and maximum temperature may be continuously maintained. Give the approximate temperature of efficient combustion, and that at which smoke is evolved from the burning coal. Why are unduly heavy emissions of smoke from a steam plant chimney generally indicative of uneconomical boiler and furnace conditions? (25)

3.—Describe the manner in which chimney or natural draught is produced, and explain how the efficiency of the draught may be detrimentally affected by :—

(1) Air leakages into flues or through boiler settings.

(2) Faulty damper gear, and excessive leakage at the economiser chains.

(3) Firebed on grates too thick, or choked by ash and clinker.

(4) Faulty brickwork or abrupt turns in flues. (20)

4.—Describe the different forms of forced and induced draught, whether produced mechanically or by steam jets. Mention some of the advantages and disabilities attending the use of the different systems. Explain why the intensity of boiler draught is invariably stated in inches of water. (20)

5.—Describe one or more of the different forms of apparatus as sometimes applied for admitting air at the front or back, or at both the front and back of a boiler firegrate. Explain the purpose of these appliances, and the conditions under which such secondary or auxiliary supplies of air might be disadvantageous. (20)

6.—Describe the methods of hand firing that should be adopted with :—

(1) Very fine slack, or coal dust.
(2) Caking or clinkering coals.
(3) Large lumps of coal.

How would the methods of firing be affected under the following conditions :—

(*a*) Firebars improperly spaced, or badly burned on the upper surface.
(*b*) Insufficient draught.
(*c*) Intermittent control and consequent fluctuating supply of feed water.
(*d*) Coals with a high percentage of volatile content. (25)

7.—Describe some of the different factors which determine the proper area of a boiler firegrate, and explain the circumstances under which a recent increase in the temperature of the flue gases at boiler exit may not be indicative of a correspondingly increased loss of heat as compared with former conditions. Mention some of the points which must have attention in any endeavour to secure a maximum difference of temperature between that of combustion on the firegrate and that of the flue gases at exit. (25)

8.—Describe the conditions of service under which mechanical methods of stoking could reasonably be expected to be more satisfactory than hand firing. Explain the operations of two distinct types of mechanical stokers, and mention some of the points regarding operation and maintenance, which should have attention to ensure the most efficient and economical results. (25)

9.—Name the different gases that are produced as a result of (*a*) the efficient combustion of coal, and (*b*) imperfect combustion of coal. How is the production of the different gases affected by :—

(1) Low furnace temperature.
(2) Insufficient draught.
(3) Excessive draught.
(4) Firebed too thick.
(5) Holes in firebed, or bare places on firegrate. (25)

10.—Explain the methods of measuring boiler draught by means of gauges, and describe the construction and operation of :—

(1) The Orsat flue gas analysis apparatus.
(2) One or more forms of CO_2 recorders or indicators. (25)

11.—Explain the principal points of difference in the construction of the following types of steam boiler :—

(1) Lancashire type.
(2) A water tube boiler.
(3) A marine, or locomotive type fire tube boiler.

Describe the construction and action of the different mountings which are common to all types of boilers. (25)

12.—Explain the differences in the condition of :—

(1) Wet saturated steam.
(2) Dry saturated steam.
(3) Superheated steam.

Describe one or more methods of steam superheating, and mention some of the advantages and disabilities attending the use of steam in a superheated condition. (25)

13.—Describe the different methods of feedwater heating that may be used singly, or in conjunction, and explain the advantages claimed when a boiler is fed with high temperature water. Why is it sometimes advantageous to soften or purify the available feed water, and what would be the probable effects of allowing greasy water to enter a boiler ? (25)

14.—Why is there a liability to excessive smoke emissions from a steam plant chimney when :—

(1) Rebuilding the firebed after cleaning out, or clinkering.
(2) Intermittent control of feed water supplies.
(3) The boiler heating surfaces are fouled by sedimentary deposit or soot.
(4) Damper gear in bad order, or flues choked with flue dirt. (20)

15.—Mention the more important points which should have attention in a complete modern boiler room plant to prevent losses of heat and thus ensure the economical production of steam, without excessive emissions of smoke from the chimney. (25)

The different points referred to in the examination questions, as set forth, are previously so fully discussed during lectures, illustrated by numerous lantern slides and diagrams, and dealt with in home exercises, that, providing a student is capable of using a pen, he generally has little difficulty in obtaining the required percentage of marks, and, as a consequence, failure to satisfy the examiner is a very exceptional occurrence. It may be urged that it is beyond the capabilities of many of the older

firemen to pass successfully through the ordeal of a written examination, but, even if this be true in exceptional instances, it only emphasises the necessity for administrative proficiency in such phases of boiler management as have a bearing on smoke abatement, and a capacity on the part of those to whom such a fireman is directly responsible, to benefit by the study of technical literature, or attendance at a course of lectures.

Whether it be a desire for fuel economy, or smoke abatement, or both, in this, as in most engineering problems, the judicious attention to unobtrusive details has a more important bearing upon the ultimate degree of success than the mere adjustment of such obvious happenings as are patent to all and sundry. Hitherto, physical fitness, combined with some previous experience with a firing shovel, have generally been considered the most essential credentials when ascertaining the capabilities of a steam boiler fireman, and the statement, as sometimes made by makers of boiler room adjuncts or specialities, that " no skilled attention is required " is not very helpful in this regard. The firing shovel, the most primitive form of flue damper, the simplest draught gauge, mechanical stokers, or mechanical contrivances for controlling draught, or feed water supplies to boilers, flue gas temperature indicators, combustion recorders, and so on, all require at least an elementary knowledge of the laws governing the combustion of a fuel to ensure intelligent manipulation. So far as the boiler fireman is concerned, it has already been shown that the acquisition of this elementary knowledge regarding the changes that occur to a fuel during oxidisation, or to a liquid during vaporisation, does not necessarily entail mathematical or other academic attainments, and hence it will be obvious that the average steam plant attendant is quite capable of appreciating the applicability of the many different points which may be discussed during a course of lectures relative to the management of steam boilers and smoke abatement.

The measure of success, however, will be greatly enhanced if the lecturer shows a sympathetic knowledge of the many disabilities under which a fireman is sometimes expected to meet the demands for steam, particularly with regard to repeated or intermittently abrupt changes in the grade and consequent unsuitability of a considerable proportion of the coal with which he has to deal, combined with the more or less acute maintenance troubles common to modern boiler room practice.

Furnace and Tank Boiler Design

by W. H. Casmey, Burley-in-Wharfedale.

Allow your minds to wander back in imagination to the Autumn of the year 687, and you see a monkish figure gathering blackberries in an old quarry at Glastonbury, Somerset.

During his rambles he came across a piece of black stone where a slide of the hill-side had taken place, and which, as we know now, had exposed an outcrop of coal.

He carried his lumpof black stone to the monastery, and the Prior, after examination, said it was merely stone discoloured by the wet soil and atmospheric action, and told his man to throw it on the fire ; wood was then the only fuel.

The black stone soon began to improve the appearance and heat of the fire, and the head of the monastery sent his man to fetch more of the same kind of black stone ; this was the birth of the coal fire in Great Britain and was kept a secret by the monks of Glastonbury for 100 years, and the secret was then shared with one of the Northumbrian monasteries, which probably accounts for Newcastle coal being the first used in London.

For 1237 years then, we have been burning coal, during which time many Royal Commissions and others have discussed the problem of how to avoid making black smoke. Londoners were not allowed to use coal during the sitting of Parliament, and one man was hanged for doing so, and now we, like our ancestors, are met to consider the old, old problem, " How to burn coal, without making smoke."

In my booklet on Coal Economy, published by Charles Griffin, London, is the following paragraph which appears applicable to a meeting on smoke abatement :—

> " Our annual burnt offering to the National goddess Extravagance is approximately 50 million tons of coal, in preparing which, 150,000 men are occupied daily, also 400 locomotives and 15,000 railway wagons, and yet for years our united cry has been ' Economy '."

I have no intention of going over a lot of laboratory detail, but state right now that the chief cause of smoke and its resultant coal wastage is not, as is often stated, due to careless stoking, but generally to the conditions under which the firemen have to work and over which they have no control.

The necessary alterations to convert a smoky chimney and wasteful boiler into the opposite is simple and inexpensive, and yet the change will as a rule effect a coal saving ranging from 100 to 150 tons of coal per boiler per year.

I am quite prepared to cure the smokiest chimney in Manchester or Salford in a couple of hours, on the simple condition that half the value of the coal saved during the first three months after the change, shall be paid to St. Dunstan's Home for the Blind.

With the general trade of the country still on the decline, the wasteful conditions of the boiler house inferred should not be allowed, especially as to make a change of a most profitable nature, as already stated, is easily effected ; all we require is a high initial temperature in the furnaces, and a low terminal temperature ; in other words, the most efficient boiler is the one which takes the biggest bite out of the temperature produced.

Boilerology of the tank type, the only kind I am considering, really commenced in a practical way about 160 years ago by the introduction of the Cornish boiler, which, as many of you know, is a boiler with one furnace flue of equal diameter throughout.

Soon after the first steam-driven mill started in Bradford in 1800, demands were made for more steam, and in 1811, according to an engineering writer, Mr. Burge, a boiler was brought forward fitted with two furnace flues which, like the flue in the Cornish boiler, were of equal diameter throughout ; and I believe this was the original Lancashire boiler, at any rate the first one carrying that name.

Between 1811 and 1873 many designs of boilers were brought forward, all more or less following the original design, but in the last-mentioned year the Lancashire boiler appeared with the diameter of the furnace flues at the rear end of the boiler contracted about six inches, thereby reducing by 30 per cent. the outlets for the products of combustion, therefore minimising the duty and efficiency of the boiler.

In 1906 a further tank boiler was introduced, six feet shorter than the standard Lancashire, but fitted with two furnace flues ; these, however, are made with their minimum diameter at the furnace end, then expanding all the way to the rear end. The natural effect of this expansion is to allow the suction of the chimney to operate directly on the fires, thereby increasing the quality of combustion and preventing the formation of smoke.

The expansion of the flues also locates the water in the boiler in proportion to the flue-heating surface and temperature of the gases, thus giving uniform ebullition and increased transmission of heat per pound of coal burned.

I would here state that no single invention has done as much as the Lancashire boiler in building up our industrial world, and any improvements made in this type of boiler reflect additional credit on the man who designed the first one, introduced in 1811.

It is well known that the height and sectional area of the chimney bears a constant proportion to the area of the boiler furnaces on which it operates ; it is, therefore, self-evident that, to be economical, the ratio between furnace area and that of the outlets from the furnace flues, through which the products of combustion pass, must be the same in all sizes of boilers ; whereas at present this ratio varies in all diameters of boilers, from 4 to 1 in a boiler 7 feet diameter to 2 to 1 in a boiler 9 feet 6 inches diameter. The larger this ratio, the greater the smoke emission and the less steam generated.

Assuming, now, we have one each of the three boilers mentioned, all 8 feet diameter, and operated by a constant fan or chimney suction, equal at the ends of the furnace flues to 1500 feet per minute, and that the volume of gases at that point, due to increased temperature, is three times greater than that entering the furnaces, what is the coal-burning capacity of each furnace?

The 30 feet long by 8 feet diameter boiler of 1811 had two furnace flues 3 feet diameter throughout, the outlet area being 14 square feet, the grate area 36 square feet, and the draught equal to 1500 feet per minute, sufficient to burn 34 pounds of coal per square foot of grate, the hourly coal consumption would, therefore, be 1254 pounds.

With our modern 30 feet long by 8 feet diameter boiler, the furnace flue diameter front end is 3 feet 2 inches, therefore 38 square feet of grate ; the diameter of the furnace flues rear end is 2 feet 8 inches, total area of outlet 11 square feet, the air supply capable of burning 30 pounds of coal per square foot of grate, or an hourly consumption of 1140 pounds.

The third boiler, patented in 1906, is 24 feet long by 8 feet diameter, flues at the front end 33 inches diameter, and at the rear 39 inches diameter ; therefore, grate area 33 square feet, area of outlet from the furnace flues is 16·58 square feet, the air supply being sufficient to burn 40 pounds of coal per square foot of grate, or an hourly consumption of 1322 pounds.

Assuming for comparative reasons the three boilers give equal evaporation per pound of coal burned, say, 7 pounds, the 1811 boiler, the original Lancashire, will show an evaporation of 8778 pounds per hour, the modern Lancashire 7880 pounds, and the 1906 boiler 9258 pounds, and so long as draught and coal supply are constant, the results cannot change.

The above figures can be verified by anyone caring to go to the trouble, and they show how the ratio of furnace area to outlets at the rear of the boiler influences the duty and efficiency of the boiler ; the same was proved by Mr. Michael Longridge nearly 30 years ago.

The 1811 boiler has a ratio between grate and outlet of 2·5 to 1, and evaporates 238 pounds of water per square foot of grate. The modern Lancashire has a ratio of 3·4 to 1, and its evaporation per square foot of grate is 210 pounds ; the 1906 boiler's ratio is 2 to 1, and its evaporation per square foot of grate 280 pounds.

By reducing the length of the grates of the two first-mentioned boilers, until the ratio between grate and outlets from the furnace flues is 2 to 1, the coal consumption would be increased per foot of grate, thicker fires would be maintained and the excess air proportionately reduced.

By reducing the excess air, combustion improves, the furnace temperature increases, and flame instead of smoke is produced ; and with the prevention of smoke, the efficiency of the boiler, *i.e.*, the evaporation of water per pound of coal, naturally increases.

Up to 18 years ago there was no rule for the sizes of the external flues of steam boilers, but along with the 1906 boiler the writer made suggestions to his firm relative to standard sizes of flues, and such were adopted and have given entire satisfaction.

The following data contain the necessary information for keeping a smokeless chimney :—

> Area of furnaces, twice the area of exit from furnace flues ; distance from top of bridge to crown plate, one-third diameter of furnace flue in widest part ; distance from back end of boiler to brickwork, equal diameter of one furnace flue ; bottom flue depth, half diameter of boiler ; width of side flues, one-seventh diameter of boiler.

The modified furnace here referred to was submitted to the Ministry of Munitions Inventions Board in August, 1917, and in November, the same year, after three months' experiments by experts, was recognised by a Government cash award.

That the subject is not merely of an academic nature may be judged by the following extracts received from steam users, and there are hundreds of other firms benefiting by the adoption of the 2 to 1 suggestion.

Extracts from Letters Received

(1) We have four Lancashire boilers, 30 feet by 8 feet, by 120 lbs. pressure, machine-fired (coking stokers) grates were originally 6 feet long, but are now 3 feet 10 inches long. On the four boilers we are saving nearly 800 tons of coal per year. Our overall efficiency is over 84 per cent. We use induced draught.

(2) Two 30 feet by 9 feet Lancashire boilers, 160 lbs. working pressure, sprinkling stokers used, length of grates

3 feet 6 inches, deadplates being 2 feet 6 inches long; engines 800 H.P.; evaporation per pound of slack, 9 pounds.

(3) Three 30 feet by 8 feet 6 inches; boiler grates reduced from 6 feet 6 inches to 4 feet; saving in coal over 20 per cent.

(4) 30 feet by 8 feet boiler, 160 lbs. pressure; reduced the grates from 6 feet to 4 feet; saving in my coal bill equal to 140 tons per year over a period of 21 months.

(5) We have three Lancashire boilers 30 feet by 8 feet; have reduced grates from 6 feet 6 inches to 4 feet; have made a saving in fuel at the rate of 9 cwts. per 12 hours' shift—this over the last six months.

(6) Since reducing the length of our boiler grates from 6 feet to 4 feet, we have saved 10 per cent. in fuel.

(7) We have reduced our 30 feet by 8 feet boiler grates from 6 feet to 3 feet 9 inches, and have saved 2 tons of coal per week over the last 18 months.

(8) Have reduced boiler grates by one-third; have reduced coal bill and stopped black smoke.

It would be easy to mention over 100 different works where the 2 to 1 ratio is now in operation, and as the idea is public property, and does not affect anyone financially beyond those who adopt it, there is no reason why a very large percentage of steam users should not reduce their coal consumption by 100 to 160 tons per boiler per year, and in some cases considerably more.

A fire to be effective should not be less than 10 inches thick, and it should be maintained at its maximum temperature; this can be done by stoking it when at its best, for the liberated gases then quickly ignite, and heat, instead of smoke, is produced.

The writer would not advocate any kind of forced draught by means of steam jet blowers, since after the jets have in some cases been working a few weeks the nozzles increase in size, and often 10 per cent. or more of the steam generated in the boiler is used by the jets.

Another objection to this practice is the smut question, and it is no uncommon thing to find the district around works where steam jets are used covered with fine particles of carbonised coal dust; this is a most common practice of wasting fuel.

Mr. David Brownlie, some years ago, carried out an elaborate series of boiler tests, and the average efficiency secured with the 1000 boilers was less than 57 per cent.; average length of grate 6 feet, average CO_2 7·6, which equals nearly 30 pounds of air per

pound of coal ; average size of boiler 30 feet long by 8 feet diameter, and coal consumption about 20 pounds per square foot of grate.

With coal of 12,500 B.Th.U.'s calorific value, and 30 pounds of air per pound of coal, the evaporation from, and at 212 degrees, is 7·7 pounds of water per pound of coal burned. Twenty-two of the boilers Mr. Brownlie tested gave 80 per cent. efficiency, which equals 10·3 pounds of water evaporated per pound of coal burned, but 172 of them were working at less than 50 per cent. efficiency.

In the first case, with the air supply of 30 pounds per pound of coal, the water evaporated per ton of coal was 17,238 pounds, but with 80 per cent. efficiency 15 cwts. of coal gave the same evaporation.

The furnace temperature with 14 per cent. CO_2, *i.e.*, 16·4 pounds of air per pound of coal, would be about 3000 degrees, but with 7·6 per cent. CO_2, air supply 30 pounds of air per pound of coal, the furnace temperature would be less than 1500 degrees.

The above illustrations explain clearly the underlying principle of the modified grate, and why a furnace 40 square feet in area, fed with air and coal in the proportion of 33 to 1, will only generate the same number of heat units for 20 cwts. of coal as 20 square feet of grate will generate for 15 cwts. of coal, when the air and coal are in the proportion of 16·4 to 1.

If boiler fires are kept 6 inches to 8 inches thick and stoked on the sides alternately, but stoked when the fires are at their best and not more than 3 or 4 shovelsful of coal used at one stoking, smoke cannot be made, it is quite impossible.

Mr. ALEXANDER MUNRO (Glasgow) said he was Convener of the Air Purification Committee at Glasgow, who were keen on purification of the atmosphere. He had been interested in Dr. Dunn's paper on "Pulverised Fuel," and wished to refer to the latter part of it where the author referred to dust or ash going up the chimney and being spread broadcast over the city. That problem had been solved in Glasgow. At the gasworks there a plant had been installed which was known as a "Dust Arrestor." It was made by Messrs. Davidson. It was guaranteed to take 90 per cent. of the dust which otherwise would pass up the chimney; as a matter of fact the dust got to the base of the chimney and was checked there. The other day, on a test with six Babcock boilers burning ordinary gasworks breeze, they collected a pound of ash

for every minute during the night and day that the chimney was operating, and on a further test one and a half pound per minute was collected.

By another method they effectively prevented black smoke. The Ljungström Preheater, a Swedish patent, had been installed. The air passed through a drum and was heated to 420 degrees before entering the furnace door. They were getting 100 per cent. more out of the flue gases by the Ljungström Preheater than they got by the best economiser. It was adopted for the purpose of economy of fuel, but they had discovered that when it was judiciously used it became practically impossible to make black smoke. He had tried and failed, although he put on two fires, one with nuts and one with ordinary washed coal.

With regard to the paper on The Smoke Inspector, he would have preferred that his friend, Mr. Park, their chief inspector, should tell his story, but he might say this : There had been some talk about having control over boiler furnaces. In Glasgow they had Borough Acts whereby they could deal with smoke from every kind of apparatus. Mr. Clinch had hinted that the power to prosecute for black smoke fell into disuse, and things became as bad as ever. In Glasgow, if a man persisted in causing black smoke, he was fined again and again. He could be fined up to £5, and that was the amount imposed every time. The cases were not dealt with by the magistrates but came before the Stipendiary. The Stipendiary, and no other body, dealt with the smoke cases in Glasgow ; so no magistrate could be influenced. The reason for that was that formerly magistrates were being influenced ; when a case came before them they passed it over with an admonition or with a very light fine. So it was taken out of the hands of the magistrates and put into the hands of the Stipendiary, with the result that in 100 per cent. of the cases which came before him there was a fine every time. Not once had their smoke inspectors failed in a prosecution.

He wanted to point out further that in Glasgow they did not talk about black smoke but about excessive smoke. Some people put on a lot of refuse and the stuff came out of the chimney in a

greenish-white smoke, and formerly they could not prosecute because the Act said " black smoke " ; now, under their Act, it was " excessive smoke." People were given two minutes ; if the smoke continued longer than two minutes they were fined. The smoke inspectors were paid good wages ; the Committee expected good work, and they got it.

Glasgow and Manchester, and other big cities, had got to tackle this question at the fountain head, and not dally with it. They had got to show that they were in earnest, and something would happen. There had been too much of the drawingroom about it up to now, and they had got to get down to practical politics.

Another thing was the teaching of firemen. The smoke inspectors had instructions from the Air Purification Committee, which was a sub-committee of the Health Committee, that they could go into the works where black smoke had been produced, and show the firemen how to prevent black smoke, giving them whatever information was possible. They believed it was no use to fine a man for a thing unless he found out why he was being fined.

He was very much interested in Mr. Hodgson's paper and wanted to put a question to the author. Mr. Hodgson talked about excess air and burning the product to CO_2. What was his opinion as to excess air, was it good to have one per cent. or two per cent. of CO ? The average fireman did not understand what was meant by " excess air." He drew his damper and where 250 cubic feet of air was needed in theory he always got 500 or 600 cubic feet, with the result that he was cooling his boiler instead of heating it. They had taught their firemen just to have a touch of the blue flame in the fire, which a man could easily judge ; and they reckoned that one per cent. or two per cent. of CO in the air, as against excess air, was more economical, and did not give black smoke.

Mr. A. L'Herminier (Combustion Engineer) mentioned he had been interested in pulverised fuel firing for the last seven years, and he firmly believed this was the only mode of burning coal efficiently and smokelessly.

The low average boiler efficiency of 58 per cent. mentioned in this country was probably mainly due to the extensive use of the Lancashire boiler, which was very wasteful; also, when considering water tube boilers, very often to the improper design of the furnace.

Up to now furnaces have been designed to suit a limited boiler evaporation, which in the interests of boiler manufacturers has until recently been kept very low. These boilers answered their purpose a few years ago, but, say, in power stations with the ever-increasing daily peak load, the boilers have to be pushed, and as the furnaces have not been designed for the work which the boilers can do, the increased evaporation is obtained to the detriment of the furnace efficiency, and often with emission of large volumes of smoke.

It is now a common practice in the United States to design furnaces which are limited by the boiler evaporating capacity, such limit being clearly defined by any tendency of priming and the degree of superheat required.

In order to obtain the best combustion results when burning pulverised fuel, the furnaces are now designed so that it will be possible to evolve 16 to 20,000 B.Th.U.'s per cubic foot per hour, this rating to be understood when furnaces are fitted with water screen. By the introduction of the water-cooled walls, this figure can be raised to 25,000 B.Th.U.'s.

With boilers fired with pulverised fuel it is easily possible to maintain an average efficiency of at least 80 per cent. day in and day out, while there are very few stoker plants which show an average efficiency of 70 per cent. the year throughout.

Better control of fires should be possible by introducing easily understood "Recording" apparatus, such as the Bailey Meter, showing at the same time the steam flow, the air flow and the temperature of gases in the flue.

The evaporation of the boiler being in direct proportion to the air flow in the furnace, where combustion is maintained under the

same condition it is an easy matter for the fireman to take care that the air flow line is following the same path as the steam flow line, instead of talking to him about excess air, CO_2 and CO, which terms he does not always grasp in the right direction.

In utilising the above apparatus in connection with the electrically-controlled pulverised fuel furnace, it becomes possible for one man to be in charge of the firing of a number of boilers, the control being effected from one main switch panel, such as is done in the Detroit Ford Plant, where two men can control an ultimate steam production of 2,800,000 lbs. per hour.

Mr. C. E. STROMEYER said to deal with a subject like this in five minutes was practically impossible ; he would therefore not attack any particular problem but would speak about the smoke question generally as influenced by the papers they had had that evening. They started with the idea that the League wanted to stop black smoke. Then they were told that the black smoke was nothing, that the harm was done by the invisible acids, which was in harmony with the feeling he had always had. Then they heard that the League was very anxious for prosecutions, to get new laws and more power ; however, one inspector had said no good was got by prosecutions. Another speaker, a fierce inspector he thought, was going to send them all to the Lord High Executioner (Laughter).

He thoroughly wished that they could get rid of smoke, and especially the injurious invisible portion, but he did not see that they were setting about it in the right way. If the League would teach them how to prevent smoke, and not invoke the law against those who could not help themselves, it would be far better.

Mr. Wollaston had referred to him as saying that engineers could solve the smoke question. He did not believe they could. Inventors and patentees he did not trust any more than he did an expert witness (Laughter).

The great trouble in Lancashire was that the boilers were overworked. In factories laid out years ago the power requirements had increased, but the boiler houses could not be extended,

and the result was that the boilers were overworked and smoke could not be avoided. But by putting in patent appliances the power might be increased and smoke also reduced, but then they had trouble with the boilers and got over-heating. He had come to the conclusion that they could not go beyond certain limits in smoke prevention or fuel economy. If the limit were passed they had boiler troubles, which were expensive and therefore uneconomical.

Water tube boilers had introduced a new feature in this respect, in so far as that intensely high temperatures were obtained in brick furnaces, and high temperatures were very favourable for the thorough combustion of fumes. But unless they were going to scrap the Lancashire boilers, and he thought there must be something like 120,000 Lancashire boilers, he did not see how they were going to make the country into the paradise expected. But even the water tube boilers made just as much carbon and sulphurous acid as the Lancashire boiler did, and the serious injury done by this gas, as explained by Sir Frank Baines, would only be intensified.

Mr. A. Bradshaw (Manchester Corporation Smoke Inspector) said in Manchester the owner generally took a great interest in boiler plant now. He did not use to do so but, like the Scotsman, they had taught him to do it, and he thought they were very well respected for doing it. They did not harass the owner but always tried to assist him in preventing black smoke. Mr. Hodgson, for whom they all had great respect, was the missionary of smoke abatement in Manchester, he did not come second to anybody; and he had taught them how to stop it. He was a trained engineer. They went about to works and tried to teach the firemen how to prevent the smoke. If the firemen did not tell them anything they were not desired to do so. What they wanted to know about the boiler plant they learned when they went into the works, and they told the responsible person where the boiler plant was wrong and advised him to put it right. If that were not done and the nusiance continued—Minshull Street. This had had a very soothing effect upon some. One or two had been very nasty,

but a few visits to Minshull Street, to appear before Mr. Brierley, soon cured them, because they were punished with a £10 fine. They could not go higher in Manchester. He did not know what was done in Glasgow. After these people had been punished a few times with a £10 fine they usually decided that it was better to put in a new boiler or do something to put it right.

During the coal strike the smoke inspector's job was hardly worth calling a job. They were walking about doing nothing with the exception of watching firms that had got cheap burners with cheap oil. If the oil companies had not been greedy and grabbed at such big profits, and had kept their oil down to about £3, many firms, he thought, would not have gone back to coal. There was talk about pulverising coal and getting oil by low temperature carbonisation. But the magnates squeezed all the profit possible out of the manufacturers. If they would be content with a reasonable profit and let the oil come to the market at a reasonable price, if it could be brought down to about £3 a ton—he was told yesterday it was £4 5s. a ton—he was sure a lot of the firms would go back to oil, and people would be able to see the sun once more.

At dinner time that day he was on an observation post in the city. They stood there not less than ten minutes, from ten minutes to two until two o'clock. They were looking towards the Exchange, at the tower, and at first could see it quite plainly and distinctly, but in ten minutes it was absolutely in a mist; they had lost sight of it altogether. Everybody had got back and started up the office fires.

In all offices in the large cities central system of heating ought to be enforced by the Government.

In the Manchester Exchange building if everybody was allowed an office fire there would be 357 separate fires going at once; as it was there was only one or two Lancashire boilers which did not give very much trouble. That went to prove that if they had central heating throughout the large premises in Manchester a lot of the smoke would go.

There was another point with regard to the restaurants, the number of which had jumped up in recent years. Those people started before the smoke inspectors came on in the morning, and the whole city was under a cloud. If anyone went up into the clock tower he could see a beautiful blue sky above but not the streets below. When he came down to the solid earth he could not see the sky. That proved that if they could compel people to adopt central heating and try to keep smoke down they would do a lot of good.

Mr. C. Elliott (Hon. Secretary, Smoke Abatement League) said that Mr. Stromeyer had suggested that the League should show engineers how to stop smoke. He would refer Mr. Stromeyer to the introduction to the programme, where the objects of the League were very briefly described. It contained these words: " The League is not a technical body, but aims at securing the co-operation of qualified persons." They were trying to induce engineers and those who were qualified to take some interest in the question and apply their intelligence and abilities to the solution of the problem. In some cases they were quite indifferent. They had invited the engineers to come. That was a move in the right direction. It was with that kind of co-operation they hoped to succeed, but they themselves were not a technical body.

Mr. Stromeyer: I think you ought to be educational. You would flourish more if you were educational.

Mr. Elliott: We are endeavouring to get engineers and others to co-operate in the education of everybody.

Mr. S. H. Gibson (Engineer to Colliery Proprietors) said he was connected with the colliery people who, for the last ten years, had been burning powdered fuel smokelessly. But he must disagree with Dr. Dunn with reference to the question of ash. It might be that Dr. Dunn had found at Ford's works and other large places that there was no ash deposited round about the chimney, but it might not be so in the case of the small consumer where the unit was a small one. When considering powdered fuel one had also to go into the question of the small

consumer. They could burn probably up to 150 tons per week and they undoubtedly got ash, a very large quantity of it. On any dry day he could get three to four pounds of it within a radius of fifty or sixty feet from the chimney. Imagine for a moment the result if these small units were multiplied in a city like Manchester. The quantity would depend upon the ash content of the coal, but there would certainly be a large deposit of ash round about the boilers and in the streets unless special precautions were taken. The chimneys would have to be at a very high altitude so that it would have every opportunity of being blown away.

They had no smoke except when the fuel was damp. They had no trouble with reference to burning, and no stoppage, or very rarely, in the tubes or pipes. He was certainly greatly in favour of powdered fuel. It was easily manipulated, and if care was taken one had no trouble with it, but the ash remained about the boiler, which was a Bettington.

Mr. E. C. Mills (Consulting Engineer) said he was in agreement with Mr. Wollaston on the main point. They both believed that the day of throwing coal on the boiler fire ought to be ended. That method should be abolished, it was out-of-date, unscientific, absurd ; it should be replaced by gasification of the fuel before it was burned. Gas was used satisfactorily in other departments ; it was replacing so many things and solving so many problems in domestic work and in metallurgical work that it could certainly be expected to effect economies in steam raising.

Every particle in the coal, every ingredient, that could be turned into gas was of high value to the man who wanted heat for the purpose of steam raising. By-recovery plants, including low temperature carbonisation plant, were extremely valuable in their own sphere, but steam raising was not their sphere at all. The ordinary user of steam, the millowner or the works-owner, did not want to put down a gasworks kind of plant. His best course was to produce gas from the coal, and then burn it, before it had time to cool and before it had time to deposit its tar. Those gases

were of more money value to him in the form of thermal units than anything he could get by selling recovery by-products.

In a paper on Gas Producers which the speaker read some years ago before the British Association he showed how, with an ordinary gas producer for making gas out of coal, the quickest and simplest way of burning it was by passing that gas into the boiler furnace and burning it straight away, with all its sensible heat of production in it, and using secondary air heated by otherwise waste heat. Of course one got a high temperature flame, but not so high as theory would lead them to think. The surfaces against which it played were all right ; they were not injured. The gases came from the producer at such a high temperature that they were very nearly at ignition point, so that they got the flame lengthened out. The clinker and ash were left behind in the producer, but a very fine dust was carried over, and that was helpful. It became incandescent, acting as radiators and giving a very high transmission of heat through the plates.

He had spent weeks and years trying to instruct firemen how to make the boiler furnace smokeless, but they never would learn. Better take it out of their hands altogether and burn gas.

Mr. E. Kilburn Scott exhibited lantern slides illustrating boiler installations at River Rouge Power Station of the Ford Motor Co., Detroit, the Union Electric Power Company's Power Station at Cahrokia, St. Louis, and the boiler of the Alleghany Steam-heating Company's installation at Pittsburg. The last-named could evaporate 400,000 lbs. of water per hour, or more than three times the output of the largest water tube boiler in this country, and equal to the output of fifty Lancashire boilers. All the steam raised was used for heating office buildings and for cooking in the restaurants and hotels in the business centre of Pittsburg.

Mr. Wollaston said that those who had contributed to the discussion having left his paper severely alone, there was really nothing upon which he need reply. He regretted that several gentlemen present, competent to express broader views in

regard to progress than had been expressed, had not seen fit to join in.

Following Dr. Dunn's modest but truly helpful paper dealing with the use of pulverised fuel, he considered the introduction of Mr. Kilburn Scott's slides illustrating American practice inopportune. As stated in his paper, pulverised fuel firing was a distinct improvement upon normal methods of burning solid fuel under boilers, but in his view it could only be regarded as "half-made gas," and he was confident that it would prove to be only a step towards ultimate gas firing. He had apologised in the paper for the possible inaccuracy of Fig. 3, but, after seeing Mr. Scott's slides, he felt that he had been too charitable towards the pulverised fuel propositions.

He was prepared to guarantee 72 per cent. all round thermal efficiency from gas-fired Lancashire boilers when using coal costing eight to ten shillings per ton less than the average boiler slack used, and to do it with absolute freedom from visible smoke or grits. He believed that similar efficiency would be obtained with coke breeze.

Dr. Dunn said no doubt such dust and ash as there was could be diminished, as Mr. Munro suggested, by dust collectors of one form or another, possibly electric separators. He believed experiments on that point were being made in certain quarters.

Bettington, of course, was the pioneer of pulverised fuel, but he doubted whether the Bettington pulveriser pulverised coal so finely as more modern ones. He would be very glad if Mr. Gibson would furnish him by post with a few samples of the coal as it went into the furnace and of the ash as it settled outside, to ascertain what their sizes were.

Transport of the dust by compressed air was no doubt in use in many installations in America, and in at least one station in Britain, but he believed the best modern practice did not use it.

Mr. Clinch said he must congratulate Mr. Alexander Munro on the success of the smoke inspection work in Glasgow; he was

already aware that in that respect Glasgow was one of the most successful towns in the United Kingdom, and the stress laid by Mr. Munro on the decision being in the hands of the Stipendiary bore out what was stated in the paper about the ordinary bench of magistrates.

He was interested to know that in Glasgow excessive smoke of any colour was an offence. That was as it should be.

Mr. L'Herminier mentioned that he used an indication of the temperature in boilers for the assistance of the firemen, instead of such instruments as the CC_2 indicator. He (Mr. Clinch) had maintained for a long time past that if a fireman was supplied with a temperature indicator he would understand it much better than he did the CC_2 indicators.

Mr. L'Herminier seemed to be much worried about the acid products of combustion. He (Mr. Clinch) took it that these acid products were unavoidable. In any case the point was, shall they be discharged as invisible gases or shall they be absorbed in soot particles? Which of the two is the more injurious? On that point he accepted the evidence of the medical profession, and if they agreed that the obstruction of sunlight by soot was the most serious factor of the smoke problem, then by all means keep the chimneys as clean as possible.

The only reply he received to the question "Who is to blame for inefficiency, the owner, the engineer, or the stoker," was a very interesting admission by Mr. Stromeyer, who excused the owners of boiler plants in Lancashire by saying that the mills had been extended since they were originally built and the boiler plants were overloaded. That amounted to an admission that the owners were responsible.

He was very interested in Mr. Bradshaw's explanation of the system in Manchester, and glad to know that it was verysuccessful, but he could not agree that it was nice for even a smoke inspector to be continually watching chimneys and hauling people into court for a £5 or a £10 fine, nor did it effect a permanent cure.

By all means pass an Act which would impose a £100 fine. Then the engineers and the owners and everybody else concerned would get together and appoint experts who would soon find a way out of making smoke. They would never get rid of it by the means of £5 fines. His aim was to effect permanent cures and so eventually put the smoke inspector out of business.

Why should not the unavoidable smoke from process work be passed through thin coke fires, raised to ignition temperature, and discharged as invisible gases ? He was very disappointed that that point had not been discussed, because he did not see any reason why it should not be done. Such places as Sheffield, and a considerable part of his own district, would be much better if process smoke were treated. He was not going to claim that it would be in most cases a paying proposition, but he did say that in the interests of the community generally it certainly ought to be done.

Mr. Hodgson said the question had been asked, whether a small percentage of excess air might not be found advantageous, and whether one per cent. or two per cent. CO might not be allowed without detriment ? His experience had been that any trace of CO was accompanied by waste of fuel, and that excess air, by cooling the furnace, might be responsible for smoke emissions. Every endeavour should, therefore, be made to eliminate CO from the flue gases.

It had also been said by another speaker, that firemen did not know anything about CO or CO_2. He had found this to be true in the majority of cases, but if firemen could be prevailed upon to attend lectures at the College of Technology, they would soon know the difference. There was nothing mysterious about these two products of combustion, and the fireman who appreciated the difference would inevitably get better results by reason of this knowledge.

In this manner, bright high temperature furnace conditions, suitable for the prevention of smoke emissions would be obtainable, or in other words, combustion would approximate to that of a

Bunsen flame. Smoke prevention was not a costly procedure, and this could be demonstrated by means of apparatus on the table, wherein smoke was made by burning coal in a tray, and afterwards consumed by passing it through a zone of higher temperature.

Mr. Hodgson also explained other laboratory apparatus and diagrams whereby the different points were demonstrated and illustrated during lectures at the Manchester Municipal College of Technology, to boiler firemen and other students, on "The Management of Stationary Boilers and Smoke Abatement."

A vote of thar ks was unanimously accorded the readers of the papers.

Seventh Session of the Conference

Thursday, November 6th, 1924.

Chairman : Mr. SAMUEL TAGG, M.Inst.C.E. (Past President of the Institution of Gas Engineers).

THE USE OF GAS IN SMOKE ABATEMENT.

The Chairman said he thought they would all remember the recorded instance of Naaman, the one-time commander-in-chief of the Syrian forces, who, suffering from the loathsome disease of leprosy, sought the counsel of the prophet for a remedy, and who, when that remedy was tried, thought it was not consonant either with the severity of the disease or the dignity of the position he held to accept the counsel. It was only under very great pressure that he adopted the very simple remedy proposed, which completely cured him. While leprosy, fortunately, was not prevalent in this country to-day, they had another scourge, the acid-corroding smoke nuisance, which was quite as injurious from a health point of view. Those responsible for the Gas Exhibit believed that the simple remedy for this scourge lay in the more general use of the smokeless products of high temperature carbonisation, namely, coke and gas. A large number of the people of this country were convinced already that that efficacious and simple remedy lay to their hands, because at the present time some twenty million tons of raw coal were used in the gasworks and the products distributed and consumed without the production of smoke. But, there was a large number of other people who were looking for a more drastic remedy for the smoke nuisance. Arrangements, therefore, had been made for eminent and distinguished members of the gas industry to address the Conference, and who, for that occasion, might be justified in attempting the role of prophets in expounding the advantages of the smokeless products which were available for

the use of the community. He thought they were all familiar with the tale of the London man who had an appointment in Manchester. Before fulfilling it, he sought the advice of his doctor. When he told him what his objective was, and enquired whether he was fit to make the journey, he was told, " No one is fit to visit Manchester." (Laughter.) Fortunately, two of the gentlemen who were to address them that evening were fit to be present. Unfortunately, Sir Arthur Duckham, who was set down on the agenda as the first lecturer to address them, had, after consultation with his doctor, been compelled to postpone his visit. He had pleasure, therefore, in asking Mr. Goodenough to address them without further delay.

The following papers were then read :—

The Fuel of the Future

By Francis William Goodenough,
Executive Chairman of the British Commercial Gas Association,
Joint Hon. Secretary of the National Gas Council.

The Essentials.

For the progress and prosperity of the country it is essential that the fuel used in our homes and our factories should—with the minimum of cost to the consumer, taking all factors into account, with the smallest necessary demand on the nation's coal resources, and with the greatest possible economy of transport—assist the manufacturer to secure maximum high quality output per square foot of factory and per head employed ; reduce household drudgery to a minimum ; preserve the valuable chemical substances in coal from which are derived the raw material for many industries ; and avoid the pollution of the air and the darkening of the skies by smoke.

Coal Our Only Fuel.

In this country fuel is the only considerable prime source of light, heat, and power ; and the only considerable supply of fuel lies in our coal-beds. We not only have no Niagara, but nothing approaching it as a source of water power. We have no native oil supplies, and our resources of wood and peat are negligible.

The subject of the coal and power resources of the country is very much under discussion at the present time. It is important to remember that, whether we use power through the medium

of steam, gas, or electricity, we need coal for its production. Electricity is dependent upon motive power for its generation. It is not a self-creative force ; it is a derivative of coal in this country (not a substitute for it), just as are gas and steam. Electricity is a means for the transmission of power, not a source of power ; a product, not a creator.

Our Prime Source of Heat and Power.

Again, it is important to remember that coal is not only our great prime home source of power ; it is also our great prime home source of heat. Therefore it is vital to our industrial prosperity to make the best use of our coal in every way. The problems attending the provision of power and heat for our homes and factories in such a way as to cheapen and improve output, abolish dirt and drudgery, supply the raw materials to our chemical industries, conserve our coal resources, and abolish the smoke curse, are separate and distinct.

Power is one thing, heat is another. They can only be confused at grave risk to national interests. The national problem is not merely coal and power, but coal as our source of light, heat, and power. The solution of the power side of the problem is mainly electricity, though by no means wholly so, as gas is the more economical in many circumstances. The solution of the heat side of the problem—whether for cooking, warming, or industrial processes—is almost wholly gas and coke. It is not within the purview of this paper to discuss the question of light ; but it may be said that, from the point of view of coal conservation, the balance of advantage is in favour of gas, though by no means to the extent that it is so in connection with heat.

The Uses of Electricity.

Electricity for light, power, and medical and scientific purposes has an immense and growing field of usefulness, and its economic development should be encouraged by every means that does not put the cost upon other industries through State subsidies. To distribute heat derived from coal in the form of electricity is, however, a most wasteful and costly proceeding, and should be clearly differentiated from the other uses of electricity. To distribute heat derived from coal in the form of gas and coke is true economy, alike for the nation and the consumer. For the evidence upon which these statements are based the community is indebted to important investigations carried out and reports made by Sir Dugald Clerk, in collaboration with Profs. J. W. Cobb and Arthur Smithells.

Its Limitations.

Owing to the report of a Sub-Committee of the Ministry of Reconstruction during the war, and to the rosy pictures painted by politicians framing a popular programme, with as a leading feature the transformations it is suggested might be effected in domestic and industrial life in every hamlet, town, and city, by the magic wand of Electra, an impression widely prevails, amongst those who have not studied the subject scientifically, that the extended use of electrical energy as a fuel—that is, for heating and cooking—as well as for lighting and power purposes, would effect an economy in the consumption of coal, would, indeed, conduce to coal conservation. The facts revealed by scientific examination put a very different complexion on the matter. The average electric generating station delivers to the consumer less than 8 per cent. of the heat in the coal it uses ; the most economical, less than 20 per cent. From 80 to 95 per cent. is now lost and not less than 80 per cent. is estimated to be lost in the largest and most economical contemplated super-station. The loss of heat in the coal used in a gas works is less than 25 per cent.

Sir Dugald Clerk, in a lecture before the Royal Society of Arts, on " The Distribution of Heat, Light and Motive Power by Gas and Electricity," showed that to do equal heating work for the consumer, after allowing in both cases for all losses in transmission and utilisation, there would be a destruction of four tons of coal at the electric generating station of to-day as compared with one ton at the gas-works, or three tons at the super-station of the future as compared with one ton at the gas-works.

The By-Products of Carbonisation.

Moreover, in the process of the generation of electricity by coal burnt under steam boilers (the most economical means known of generating electricity in large quantities other than by water power), there are destroyed all those valuable commodities so vital to our manufactures, to our agriculture, to our road and air transport services, and to our armament—benzole, carbolic, creosote, pitch, toluole, sulphate of ammonia, cyanide, etc.—which are recovered as by-products when coal is carbonised at the gas-works.

High versus Low Temperature Carbonisation.

The only established economic method of obtaining the gas and coke from coal, and securing the chemical by-products vital to us in peace and war alike, is that of high-temperature carbonisation, as carried on in the gas-works of to-day. The claims made for low-temperature carbonisation as an economic method of dealing with the coal resources of this country have not been

established, although exhaustively investigated by the Ministry of Munitions and the Fuel Research Board. Those claims were recently submitted to severe criticism by Lord Gainford in a letter in " The Times," and the answer to that letter by Colonel Thwaites (the Acting Chairman of Low-Temperature Carbonisation, Ltd.) omitted an essential quotation. He referred to a circular recently issued in the joint names of the Mines Department and the Department of Scientific and Industrial Research, and concluded his quotation with the words : " To-day it is evident that the technical problems of carbonising coal at low temperatures have been solved in all essentials." Then he put three dots. Let me supply the finish to his quotation. The report to which he referred added : " . . . . but before we can safely introduce the process with a prospect of financial success further large scale work—mainly on engineering problems—remains to be done. There have been a number of partially successful solutions. A process may make successful use of types of coal which under present conditions command little more than the price of waste products and produce a smokeless fuel which sells at the price of good raw coal, while the by-products of the process may command a price which would not be obtainable if the supply were large.

" It is one thing to evolve a process which may be a commercial success on a relatively small scale, and quite another to apply it universally. Yet it is only by the solution of the problem on a scale of national importance that any ultimate effect on the state of employment and the industrial prosperity of the country can be produced."

The Established Carbonisation Industry.

It is hardly necessary to add that had low-temperature carbonisation proved to be both technically and financially the right method of dealing with the coal resources of this country, it would have already been adopted by the established coal carbonisation industry—that is, the gas industry.

The facts that I have given are interesting, important, and, I think, conclusive, from the national and communal points of view. The case for gas fuel economy is up to that point absolutely conclusive ; but there remains to be considered fuel efficiency from the point of view of cost to the individual user, because if it is more costly for him to use gaseous fuel than to use crude coal, he will, if he is a business man, feel compelled, and if he is a private householder, be strongly inclined, to continue to use crude coal, in spite of the arguments in favour of gaseous fuel from the public point of view. This is human nature, and we cannot make it the subject of complaint—we have to deal with it as practical people.

Relative Fuel Cost.

How do the cases stand for the use respectively of (1) gaseous fuel, (2) crude coal, and (3) electricity from the individual consumer's point of view ? First of all, it is necessary to point out and to emphasise strongly the fact that in considering this aspect of the question we must have regard not merely to fuel cost compared with fuel cost, but we must take into consideration the domestic or industrial budget as a whole—we must take into account the questions of waste or economy of transport, health, energy, time, storage space, etc., to which I have already referred, before we can pass a final verdict as to comparative cost in any given case.

For continuous firing, either for industrial or for domestic purposes, fuel cost for fuel cost, gas at any price at which it can be commercially supplied to-day is dearer than coal or coke. For intermittent use, gas is generally as cheap, and sometimes actually cheaper, and by reason of its incidental economies easily holds the field.

Cost Comparisons.

The following I believe to be reliable comparisons of the fuel cost of useful heat to the consumer obtained by the use respectively of coal, coke, gas, and electricity. I have taken coal and coke at 50s. per ton, gas at 8d. per therm, and electricity at 1d. per unit.

		Per Therm of Useful Heating.*
Coal	costs from	9d. to 27d. (*a*)
Coke	,, ,,	8d. to 12d. (*b*)
Gas	,, ,,	10d. to 18d. (*c*)
Electricity ...	,, ,,	30d. to 40d. (*c*)

* That is, heat which does useful work for the user, as distinct from that wasted through the inefficiency of utilisation or through the unavoidable burning of fuel at times when heat is not needed.

(*a*) According to whether required for regular or intermittent heating.
(*b*) Only comparable in cases where fairly constant heating required.
(*c*) According to efficiency of utilisation, varying in different processes.

It will be seen that for constant use coke is the cheapest fuel if cost of fuel alone is considered. This is particularly so in regard to steam raising, as to which very important figures of practical experience have been published and are available, though space will not allow me to quote them, and they will doubtless be given in another paper.

The figures also show (and they are supported by experience) that gas used in the most favourable circumstances is actually cheaper in direct fuel cost than coal used in the most unfavourable circumstances and *vice versa*. Comparisons between the two

depend entirely upon the circumstances in which fuel is required and used.

Intermittent Supply.

For intermittent use gas easily beats all comers. No one would suggest using coke for intermittent heating, and for that reason I have included no figure for its cost in such circumstances. As an actual and striking instance of gas showing a direct money economy over coal, I may mention that at an infirmary in London some time ago gas cooking stoves were installed in all the ward-kitchens in place of coal ranges, with the result that a saving of no less than £1200 a year was effected in the fuel bill, without making any allowance for the savings effected in labour, dirt, and the heavy wear and tear on the coal ranges. The coal required to produce the gas consumed in lieu of the coal burned in its crude form shows a saving of 400 tons of coal per annum, *plus* 100 tons of coke available for sale. That is a striking, but by no means a solitary instance of gas fuel efficiency. But when we consider comparative costs when heat is required for considerable periods, there are, as I have already indicated, a number of important considerations other than actual fuel costs to be taken into account. We have to draw up a balance-sheet.

Gas effects Savings.

The substitution of gas for coal in industrial processes frequently results in the saving of so much in stoker's wages and other incidental expenses as to effect a substantial economy to the user, in spite of the cost of the gas consumed being greater than that of the coal formerly burned. Again, the use of gas in industrial processes, by reason of the constant maintenance of temperature and the possibility of exact heat regulation, frequently leads to a higher and more uniform quality of product, a much lower percentage of rejects, and a greater certainty of output. It, moreover, frequently results in an increase of output per machine per hour, and furthermore secures healthier and less exhausting conditions for the employees engaged in the operations. I could give many actual instances to confirm these statements and to show that gas enables the manufacturer to reach a higher percentage of efficiency in his processes than he could achieve with the use of solid fuel, but space and time will not permit. Where, however, after taking all attendant factors into consideration, the cost of gaseous fuel is found to be too high, coke will generally be found to be the best means of securing fuel efficiency.

The Budget as a Whole.

What is true in the factory and workshop is also true in the home. The budget must be taken as a whole. The consumer's

standpoint must, in fact, be considered not by an examination of fuel costs alone, but in the light of incidental economies of all kinds. Due allowance must be made for saving effected in connection with building costs, and therefore rents ; wear, tear, and cleaning both of the building and more particularly of its contents ; storage space for fuel, and the rent for such accommodation ; service costs—a very considerable item ; the drain upon not only the time but the nervous energy of the housewife, which, though unpaid, has an economic value ; and expenditure of nervous energy directly or indirectly by other members of the household, with its not unlikely consequences of doctors' bills or deterioration of earning capacity. Some of these factors are often neglected, but they are far from negligible ; and it would be easy to illustrate the truth that these and other matters are closely related to domestic economy, as they are largely dependent on the choice of the domestic fuel. They should certainly figure as prominently in the domestic budget as the more obvious, but often misleading, item represented by fuel costs alone.

Summary.

To sum up, I am of opinion that gas, with its companion by-product, coke—already rapidly increasing in favour and use—will by progressive degrees become the fuel of the future, because the gas-works supply to the community as gas, coke, or chemical products from 75 per cent. to 80 per cent. of the total heat value of the coal delivered to them ; because the gas-works recover from the coal the raw materials for dyes, drugs, disinfectants, motor fuel, fertilisers, etc., which are destroyed when coal is burned in its crude state ; because gas requires no road transport for its delivery to consumer ; and because gas is a smokeless fuel which can be adjusted to and maintained at the desired temperature, need only be consumed as and when required, involves no dirt or labour before, during, or after use, and has been tested and unreservedly approved as the most hygienic means of heating by thousands of medical men—because, in short, gas fulfils all the requirements set out in the first paragraph of this paper, except as to cost for constant heating, when its companion product, coke, supplies the want.

Gas Coke

In relation to Industrial and Domestic Smoke Prevention and Fuel Economy

by E. W. L. Nicol, Assoc.Inst.C.E., M.I.Mar.E., A.M.I.E.E.,
Engineer and Fuel Expert to the London Coke Committee.

The whole question of coal smoke prevention is inseparable from that of coal conservation and a fuller use of our native bituminous coals ; or, to put it in another way, the science and practice of fuel economy, and economy in fuel practice necessarily involves the prevention of smoke formation. That economy in fuel practice tends materially to promote efficiency and cheapness in production is also well known ; and it has truly been said that the dominant considerations in promoting increased production should be efficiency and cheapness. The cost of power, heat and light is a factor of prime importance directly affecting the cost of production ; and, with a view to cheapen these primary commodities, there is among our trade competitors at the present time great activity in research and development in fuel practice in all important countries of the world. In foreign countries the trend of progress is influenced in no small degree by the requirements of national defence and economic necessity. In Great Britain these factors are, or should be, regarded as of paramount importance.

With our relatively high labour costs, and our smoke problem ; and with our lack of petroleum, and the vital necessity for independent supplies of liquid fuels for our land, sea and aerial transport services, for the Royal Navy, and for domestic and industrial purposes, there exists in this country every patriotic and material incentive necessary to promote improvement and development in the utilisation of our coal resources.

The daily increasing extent to which we in this country are in normal circumstances dependent upon the diminishing resources of foreign countries for supplies of liquid fuels, and the inevitable consequences of failure to maintain such supplies, do not appear to be fully appreciated. It is indeed doubtful whether the general public realise in the least how serious the problem is, and is likely to become.

So utterly complete is our dependence upon petroleum and petroleum products of foreign origin, that even a temporary interruption or withholding of supplies would, in normal circumstances, have the most serious consequences ; and the immediate result of inadequate supplies during a period of war would be the first step towards national disaster.

Our consumption of motor spirit, for instance, was in 1922 of the order of 350,000,000 gallons, whereas the total home production of benzole at gas works and coke ovens was only 11,155,000 gallons, while the annual increment in demand, due to the world output of motor cars alone, is estimated in hundreds of millions of gallons.

In the necessary work of enlarging and cheapening production, by reducing the cost of power, heat and light, due regard must be had for the fundamental importance of these factors ; they are indeed vital realities of life which appear to be almost entirely ignored by the public and the State, except during relatively brief periods of stress which tend, momentarily, to focus opinion upon them. But it is sincerely to be desired that State action upon really comprehensive lines will at last be taken to conserve our coal resources and augment the home production of the vital liquid fuels. It is now well known that, during the war, the shortage of fuel oil and petrol nearly resulted in irretrievable disaster. It is, therefore, the plain duty of any Government to protect the country from such risks in future. Obviously, no amount of purely electrical development by means of coal-fired power stations can provide for the fuel requirements of the navy or our transport services. Coke-fired power stations, of which more will be said, fall within quite a different category. And again, failing the provision of a satisfactory substitute, the general public cannot reasonably be blamed for improperly using bituminous coal as fuel and so polluting the atmosphere with smoke. In this, as in other directions along which progress in sanitation has been made, it is the State which must by law fix the hygienic standard of the nation ; and having regard to all the facts, it is difficult to conceive how this can be done except by the provision of smokeless fuels, in adequate quantities, and in a form suitable for use not merely in existing apparatus of more or less antiquated pattern, but also for use in modern industrial and domestic heating appliances, which are now being installed in power stations, factories, and dwelling houses.

A point which, in this connection, the advocates of low-temperature carbonisation have apparently failed to grasp, is that modern heating apparatus using solid fuel, such as forced-draught furnaces and mechanical stokers, central heating and hot-water supply boilers, cooking and closed stoves, require for their efficient operation not a semi-volatile fuel such as low temperature coke, but a concentrated solid fuel containing a minimum of volatile matter.

In certain American cities, where smokeless conditions have been attained, and maintained over a long period, it is significant

that the use of "soft" or bituminous coal is prohibited. Success has attended this prohibition for the simple reason that natural smokeless substitute fuels in the form of anthracitic coal, oil, and natural gas are, or have been, available in sufficient quantities at reasonable prices.

It is equally significant that, in the United States, steps are now being taken to promote the production, and to popularise the use of coke as a substitute for the natural smokeless fuels, supplies of which are said to be diminishing and already inadequate.

No such natural smokeless fuels exist in sufficient quantities in this country. The yearly output of anthracite, for instance, totals only some four million tons, whereas the annual coal consumption for domestic purposes alone is estimated at 35 million tons, and that for steam raising, 60 million tons.

In the light of these facts, it may be interesting and useful to examine to what extent our natural coal fuels might be treated and their combustible products economically applied to industrial and domestic purposes with a view, incidentally, to eliminate the formation and emission of visible smoke, and to provide independent supplies of liquid fuels.

The facts relating to the smoke nuisance are now well understood, and the main sources of pollution have conveniently been sub-divided as follows :—

Industrial Smoke : Metallurgical and other heat-process furnaces ; steam boiler furnaces ; river steamers ; railway and road locomotives.

Domestic and Quasi-Domestic Smoke : Open fire grates ; kitchen and other cooking ranges ; wash coppers ; club and hotel steam boilers ; bakeries ; laundries and breweries.

The Smokeless Combustion of Coal.

It is not suggested that, given the necessary conditions, degree of skill, and constant attention, bituminous coal cannot be consumed smokelessly ; but the fact remains that the consumption of such coal in ordinary circumstances is the root-cause of the prevailing smoke nuisance.

Certain types of mechanical stokers and, in particular, certain types of forced draught furnaces, have frequently proved effective in eliminating the emission of visible smoke during the preliminary stages of the combustion of relatively good quality coal ; but low-grade qualities of coal, which must necessarily be utilised to the fullest extent, are less amenable to treatment in this manner.

Pulverised Coal as Fuel.

Finely pulverised coal can be consumed smokelessly and efficiently; but it is well known that the degree of efficiency attained in the combustion of pulverised coal varies with the degree of fineness; and, unfortunately, the extreme degree of pulverisation necessary to maintain a reasonably high efficiency entails the risk of emission of fine ash from the chimney with the other products of combustion.

Notwithstanding this disadvantage, pulverised coal has usefully been applied to various types of metallurgical furnaces; but its application to existing types of steam boilers on a large scale is fraught with other serious difficulties. Comparatively large furnace volume is necessary in order to obtain good results. This entails additional cost in adapting boiler plant where such adaptation is possible, and this, of course, renders the use of a substitute fuel impracticable in case of emergency; but the emission of fine ash from the boiler chimney is by far the most serious obstacle to the general adoption of this system as a means of smoke prevention. From 80 to 85 per cent. of the ash contained in the coal, it has authoritatively been stated, is dispersed from the chimney top in this way; and in cities and towns the resulting nuisance would be infinitely worse than that of smoke.

Oil Fuel.

Oil fuel has many practical advantages, but these advantages are largely offset by the fact that fuel oil is, almost entirely, an imported commodity.

Oil-firing with relatively cheap home-produced tar-oils has, obviously, many economic as well as practical advantages; and it is not sufficiently realised that creosote and tar oils, products of coal carbonisation and by-product recovery, can be consumed smokelessly and efficiently, and are so used for steam-raising and metallurgical process work.

Smoke Prevention and Coal Conservation.

The deleterious effects of coal smoke upon health and happiness, vegetation, fabrics, and agriculture are now well known; but it is remarkable how rarely one hears of a really practicable solution of the smoke nuisance. There is no lack of so-called "solutions," the most familiar adumbrated at the present time being the production and distribution, presumably upon a boundless scale, of "low temperature" smokeless solid fuel, and the production and distribution of "cheap and abundant" electricity. These expedients, however, must be regarded economically as inconclusive solutions, the realisation

of which, in any but a relatively small way, involves practical and financial difficulties apparently insurmountable.

The problem of the smokeless combustion of raw bituminous coal is one of considerable antiquity. The scientific principles involved in the complete solution of the problem have been, for several generations, well understood ; but the general application of these principles to everyday conditions of use in the industries, and in the home, has been found to be impracticable.

It is also well known that smokeless combustion and efficient combustion are largely synonymous terms : the attainment of one condition is almost inevitably followed by the other ; and reference to the Patent Office records will show that thousands of patents have been granted for inventions relating, directly or indirectly, to improvments which aim chiefly at the more efficient or smokeless combustion of bituminous coal.

Indeed, so long ago as the year 1858, a prize of £500, won in open competition, was awarded to an inventor for a smoke-consuming apparatus which, on the highest authority, was then stated to be almost perfect in operation.

These inventions notwithstanding, and in spite of the training and skill of many engineers and scientists who have concentrated upon the subject for over a century, the smoke nuisance has in many districts steadily become worse with the increasing use of soft coal as fuel.

Increasing the Commercial Value of Coal.

By treating all classes of bituminous coal as raw material for the manufacture of smokeless fuels, fertilisers and other products used in our industries and public services, its commercial value would not only be increased, but more labour would be employed per ton of coal mined. A fuller and more efficient utilisation of our coal resources may, in fact, be regarded as one of the first essentials, not only in solving the smoke problem, but also in alleviating unemployment through the more efficient use of the land and in the development of industry.

Only a relatively small proportion of the coal produced is so treated at British gasworks and by-product recovery coke ovens. Of the 189,000,000 tons consumed annually, in this country, 139,000,000 tons are burned in the raw state ; and the proposal that no coal capable of profitable carbonisation should be used in its crude state is one that should receive immediate attention.

Against such a proposal it has been advanced by responsible authorities that great difficulty would be experienced in disposing of the principal concomitant secondary product, coke, and the unsatisfactory position of the coke market, ten years ago, certainly

gave good grounds for apprehension ; but the recent introduction of coke as fuel for steam-raising at electric and other power stations, and the development and introduction of coke-burning domestic heating appliances, have together created a steady demand for coke, so that in most districts the demand for coke should at least keep pace with any possible increase in production, which at present amounts to some 8,000,000 tons a year.

In districts where efforts have been made to demonstrate the utility and superior efficiency of coke for these purposes, it is found that the great bulk of coke produced can now be disposed of locally at prices which show a fair profit to the gas authorities, and yet, in comparison with prices charged for good house coal or steam coal, still show considerable financial advantage to the consumers.

Influence of Coke upon Atmospheric Sanitation.

The direct and growing influence of coke in mitigating the *domestic* smoke nuisance may be gauged from the following figures :—

An ordinary independent coke-fired hot-water supply boiler which, in conjunction with a gas cooker, eliminates the necessity for a kitchen range, consumes about five tons of coke per annum, as a minimum. The present monthly output of one maker of coke-fired boilers is over 400, or 4800 boilers per annum. This output alone represents an annual increment in demand for coke of 24,000 tons, which not only displaces at least an equal weight of coal, but, incidentally, entails in its production the manufacture of some 625,000,000 cubic feet of gas, which also must find a use in lieu of coal ; and there are already some forty British firms specialising in the manufacture of independent coke boilers, and other coke-consuming domestic appliances.

In the *industrial* field, the influence of coke in preventing smoke emission is no less important ; and its use for many industrial purposes has not only been proved to be practicable, but also economical. Coke is now used exclusively as fuel, in lieu of coal, in many hand-fired steam boilers of all descriptions and capacities. Coke is used also by means of a comparatively new type of forced-draught mechanical stoker, which is applicable to the largest capacity steam boilers.

Coke as a Diluent to Coal.

The Sandwich System of Fuel Blending.

Probably one of the most important directions in which coke has been introduced recently is at electricity-supply power stations. For economic reasons coke is not used exclusively,

but as a diluent to coal, and as a means thereby of not only effecting the smokeless combustion of coal, but also of facilitating the efficient use of low-grade, but relatively cheap, classes of bituminous coal which, otherwise, are often considered unsuitable, and frequently unsaleable. The importance of facilitating the efficient use of such low-grade classes of coal, from the national economic point of view, may be gauged by the fact that it has been stated on the highest authority that the quantity of this material buried in the mines amounts to some sixty to seventy million tons per annum.

How coke is made to function in this important and economical way will be clear from the following explanation of the Sandwich system of fuel-blending: Ordinary bituminous coal slack contains 28 per cent., or more, of smoke-producing volatile matter; coke contains about 2 per cent., or less, volatile matter, while *smokeless* steam coal contains about 14 per cent. Mixed in equal proportions of bituminous coal and coke, the composite fuel would have the following analysis :—

PROXIMATE ANALYSES OF FUELS USED BY MEANS OF THE SANDWICH SYSTEM.

	Coal.	Coke.	50 per cent. Coal & Coke.
Volatile matter	28·0%	1·0%	14·5%
Fixed Carbon	57·9%	89·0%	73·25%
Ash	14·5%	10·0%	12·25%
Calorific power, B.Th.U.	10,780	11,500	—

PROXIMATE ANALYSIS OF TYPICAL SMOKELESS COAL.

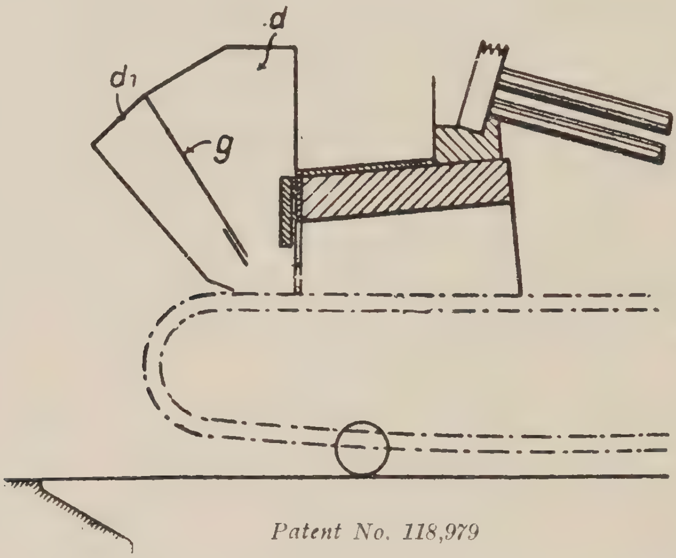
Volatile matter	14·0%
Fixed Carbon	76·0%
Ash	10·0%

From the above analyses it will be seen that the proportion of coal to coke may be so adjusted that the analysis of the composite fuel, as fed to the furnaces by mechanical means, may be identical with that of relatively expensive Welsh smokeless coal.

THE SANDWICH SYSTEM.

It should here be pointed out that it is not necessary or permissible intimately to mix the coal and coke in order to obtain the required results. Indeed, there are probably few power station engineers who have not tried and failed to burn on ordinary chain-grate mechanical stokers any considerable admixture of coke with bituminous coal. The invariable result of this experiment is a " misfire "; that is to say, the furnace is cooled to such an extent by the slow combustion of the mixture, that there is failure to ignite the fuel as it enters the furnace, and the fire " goes out."

The efficacy of feeding the coal and coke in separate superimposed layers was first discovered by the author while experimenting with coke breeze during a period of acute coal shortage. The automatic "Sandwiching" of the coke layer between the moving chain-grate and an upper layer of coal slack was accomplished by the simple expedient of fitting an adjustable division plate (*g*) in the coal feed-hopper, as shown in the diagram.



Patent No. 118,979

"Sandwich" System of feeding Coke and Coal applied to Chain Grate Stoker.

Thus the coke is fed on to the moving grate from hopper (*d*1) in a layer of any required thickness; and from hopper (*d*) a layer of coal slack is fed upon the coke layer; the correct proportion of coal to coke being adjusted by means of the guillotine doors or shutters shown in the diagram.

The precise proportion of coal to coke is determined by the analyses of the two fuels, and also by consideration of relative price and calorific power, the fuel showing the greater calorific value being used to the utmost extent consistent with good results; but, usually, a 50 per cent. mixture gives smokeless combustion and is considered most advantageous from the financial as well as from the practical view points.

That the Sandwich system of fuel blending has been used continuously for some years at several of the most important power stations in this country is sufficient proof of its commercial utility and adaptability; but the precise improvement in thermal efficiency realised at one power station by means of the Sandwich system, namely, 19 per cent., is shown by the following results of alternate tests with coal alone and with coal and coke, which have been supplied by one user :—

Results of Alternate Tests.

(1) Coal and Coke. (2) Coal only.

	Test No. 1. Coal and Coke.	Test No. 2. Coal only.
Calorific power as fired...	11,138 B.Th.U.	12,150 B.Th.U.
Fuel consumed per grate foot hour	30·66 lb.	31·66 lb.
Ash and clinker, actual	16·22%	12·7%
Average steam pressure	178 lb.	179 lb.
Super-heat temperature	486° F.	490° F.
Water evaporated per hour... ...	10,505 lb.	8,747 lb.
Water evaporated per square foot of heating surface	5·22 lb.	4·35 lb.
Water evaporated per lb. of fuel as fired, from feed temperature...	7·18 lb.	5·76 lb.
Water evaporated, from and at 212° F.	9·22 lb.	7·44 lb.
Efficiency: boiler and super-heater	69·9%	53·12%
Efficiency: boiler with economiser	79·96%	60·98%
Draught over fire	0·25 in.	0·25 in.

From the above figures it will be observed that not only is the thermal efficiency of the boiler plant very materially improved by using the composite fuel, but the evaporation per pound of the mixture, although of lower calorific power, is higher than that of the coal only; and, moreover, the output of steam per boiler is greater by 20 per cent.

The last-mentioned fact, coupled with the fact that practically smokeless combustion is maintained, enables the Sandwich system to compete successfully with pulverised coal-firing, as it ensures good results with the cheapest class of fuel and does not entail the use of coal-crushers, grinding mills, coal drying plant, special conveyors and storage bins, burners, and other accessories, nor the danger incidental to the use of pulverised coal as fuel

Power Station Engineers on Economies effected by means of Coke fired on the Sandwich System.

Engineers responsible for the operation of important power stations using the Sandwich system have reported officially as follows :—

1.—" Owing to the increased use of coke and coke breeze, a saving of £8000 a year can be effected."—London County Council Tramways Department.

2 —" Apart from the saving in money, low grade classes of fuel can be dealt with on the Sandwich system at a much

higher efficiency than would be the case if burned separately.' —Highways Committee Report to the London County Council.

3.—" Coke breeze is being burned with coal on the Sandwich system, and, although the load factor is only 25·6 per cent., the cost of fuel per *unit sold*, ·34d., is the lowest recorded this year for any undertaking in this country."—*Electrical Review, re* Darlington Corporation Power Station.

4.—" The proportion of volatile matter was approximately 8 per cent. of that of coal only. This would appear to constitute an important element in determining the thermal efficiency of the boiler, for the reason that the hydrocarbon loss is minimised due to the reduction of the volatile matter in the combined fuel. The thermal efficiency obtained showed a difference of 19 per cent. in favour of the Sandwich system." —An Important London Power Company.

5.—" After eighteen months' experience with the Sandwich system of fuel blending on a large scale at a power station using on the average 3000 tons of fuel per week, I have come to the conclusion that the use of this system has introduced quite a new line of thought in fuel use which has many important advantages from both the commercial and national points of view. Equipped with divided overhead storage bunkers, and other facilities for blending at the boiler furnaces, the combinations which can be secured are practically infinite. By means of a simple system of trial and error, the most advantageous mixture, having regard to price and all other factors, is readily determined ; and a high thermal and commercial efficiency can thus be maintained which, without the control and elasticity incidental to the Sandwich system, would be impossible."—The Power Station Engineer to one of the largest public utility authorities.

Most smoke reformers have been accused of having " an axe to grind " or some personal interest to promote ; and the above quotations taken from the reports of responsible engineers certainly do read not unlike a company-promoting prospectus ; but the author disclaims any such motive or intention. His main object is, frankly, to promote the use of coke as fuel on its merits, and thus to further the interest of the London Coke Committee. The fact that by so doing the dual causes of fuel economy and smoke abatement are also promoted has been a great incentive and encouragement ; but it is indeed gratifying to know that the introduction of coke as fuel, and the economies incidental thereto, has brought about modifications of an important character in fuel practice, not only at existing electric power stations, but also in the design of important new power stations, so that, from the outset, coke can be used, along with relatively

The above photograph of the interior of the Boiler House of the Barton Power Station of the Manchester Corporation has been reproduced by kind permission of *The Manchester Guardian*. The separate coal and coke shutes, communicating with each mechanical stoker and with the divided coal and coke bunkers overhead, are clearly seen, as is also the dividing plate (marked "g" in the explanatory diagram, page 262) which separates the coal and coke in the feed hopper.

cheap grades of coal slack, and thermal efficiencies realised which are much in excess of former experience.

It is gratifying also to find, on attending this Smoke Abatement Conference at Manchester as a representative of the Institution of Gas Engineers and the London Coke Committee, that the new power station of the Manchester Corporation at Barton, which delegates and members of the Conference have been privileged to inspect, is not only designed to operate, as and when required, on the Sandwich system of coal and coke-firing, but that it is classed officially by the Electricity Commissioners in their recent report as the most efficient power station of its class in this country.

Incidentally, and having regard to the well-known enterprise and business acumen of the Manchester Corporation, it may safely be assumed that by utilising coke or coke breeze at the power station, a new and important outlet for coke has been created, of mutual and material benefit to both the Electricity and Gas Departments of the Corporation and, through them, to the citizens of Manchester, by the provision of relatively cheap electricity and smokeless operation of the power station.

That this system of firing has been adopted by Manchester, following upon experience in London, is indeed a significant reversal of the usual order of events well worth recording; but it is still more significant that coke-firing should be adopted at Barton in spite of the promised advantages of pulverised fuel systems of foreign origin.

Conclusion.

Nothing is more certain than that the world demand for petroleum and petroleum products must ere long exceed the available world supply; and while we may enjoy to the fullest extent the felicity and prosperity which petroleum has brought us, it must be borne in mind that coal and coal products are, and must remain to an ever-increasing extent, the mainstay of our industry and power as an Empire.

It is equally certain that an adequate and independent supply of liquid fuels must remain a factor of vital importance in peace, as in war. If Great Britain and the Dominions are to escape a costly and increasingly precarious dependence upon the diminishing resources of foreign countries, our coal deposits must be made to yield the liquid fuels we require.

All authorities on the subject are agreed that our coal can, and should, be made to yield such fuels in adequate quantities; they differ only as to the method, or methods, by which the

agreed common object should be accomplished. It is quite clear, however, that whatever method or methods may be adopted, coal distillation must eventually be carried on on a scale hitherto undreamed of in this country if smokeless fuels and liquid fuels adequate to the country's requirements are to be internally produced.

The disposal of the solid product, coke, has in the past been a serious obstacle to large-scale coal-carbonising operations. The introduction of coke-burning domestic appliances and coke-burning mechanical stokers at electric and other power stations has to a large extent eliminated this difficulty.

The development of power from our coal resources must, in fact, begin with distillation and by-product recovery ; and the carbonisation of coal can be carried on commercially on an adequate scale only by gas supply authorities who possess not only the necessary knowledge and experience, but also the means of distributing and marketing the gaseous and other products of the process.

From the national economic point of view, electricity generated directly from raw coal is, relatively, a wasteful means of converting and distributing potential energy, 80 per cent. of heat value of the coal being lost in the process, and also the whole of the recoverable by-products. Coke-fired power stations stand, economically, in quite a different category.

The coke at present produced at British gasworks, *i.e.*, 8,000,000 tons per annum, is more than sufficient to produce smokelessly and efficiently the whole of the electricity publicly distributed in this country ; and the output of coke is increasing daily.

At several of the largest power stations in London and in the provinces coke is now used, on its merits, in conjunction with low-grade coal slack by means of the Sandwich system of firing. These power stations are among the most efficient from both the thermal and the commercial points of view ; and from the national economic point of view they undoubtedly are the most efficient power stations. Apart from its smokeless characteristic, and compared with raw or pulverised coal, the practical and economic advantages of coke as fuel for the production of power include the following :—

(1) There is practically no difference between the gross and net calorific power of coke.

(2) Coke requires less furnace volume than coal.

(3) Coke facilitates the use of low-grade coal, which is now, according to the highest authorities, rejected and buried

in the mines to the extent of 60 to 70 million tons per annum.

(4) Coke is smokeless, and it requires the minimum excess of air to effect its complete combustion.

(5) The efficiency of combustion of coke under suitable conditions is about equal to that of pulverised coal.

The advocates of powdered coal have stated that one of its great advantages is that it eliminates the necessity for removing ash and clinker, simply because 80 to 85 per cent. of the ash is projected from the chimney shaft. No difficulty of this description has arisen from coke-fired boilers.

TABLE 1.

Specimen Daily Records of Coke-fired Lancashire Boilers.

Date.	Economiser. Inlet. Deg. Fahr.	Economiser. Outlet. Deg. Fahr.	Pounds of Water evaporated per Pound of Coke as fired. Actual.	Pounds of Water evaporated per Pound of Coke as fired. From and at 212° Fahr.
June 27th	120	240	9·06	10·18
28th	115	225	8·31	9·35
29th	120	215	8·67	9·74
30th	120	210	8·45	9·49
July 1st	120	215	8·84	9·93
3rd	120	210	9·0	10·11
4th	120	230	9·38	10·45
5th	120	225	8·93	10·02
6th	120	225	9·03	10·14
7th	120	225	8·60	9·66
8th	120	240	9·16	10·29
9th	115	225	9·02	10·13
10th	115	225	9·52	9·57
11th	110	230	8·87	10·05
			Average ...	9·9 lb.

Note.—The above Boiler Data are taken from the Boiler Log Sheets of one of the most important London Public Institutions. An ordinary Lancashire boiler having 36 square feet of grate area, and fired with coke exclusively at the rate of 18 lb. per sq. ft. of grate area per hour, would evaporate, on the above basis, over 6000 lb. of water per hour. This rate is seldom exceeded by boilers fired with ordinary low-grade bituminous coal.

Mrs. Gee, who spoke from the point of view of a housewife by profession, said that like most professionals she had a hobby, and that hobby was speaking at women's meetings upon smoke abatement. She found certain objections expressed at those meetings to the use of gas as a fuel. There was very little objection to it for cooking and washing. In regard to its use for heating purposes, people believed that it was injurious to health, and for this point of view she believed they had to thank the doctors who were very prejudiced against its use in the district of the city in which she resided. One doctor always advised his patients to have their gas fires taken out. If the doctors could be converted, then the general public would have a more open mind. Another objection was the cost, which was high as compared with coal in a working-class household. Those who had servants had no idea of the economy practised with coal in a working-class home. After the cooking was done in the morning, old salmon tins and fruit tins were filled with small coal and potato peelings and put at the back of the fire for economy. Gas would have to be much cheaper before working people would be persuaded to use it. In Manchester, the people had to pay for the hire of the stoves, thus also adding to the expense. Also, many people liked to see the cheerful blaze of a coal fire. If engineers could give them gas fires they could use a poker to, possibly some of the prejudice to them might be overcome. (Laughter.) An Englishman dearly loved a poker. It represented safety if there was a burglar in the house, and if he came off worse in an argument with his wife he could turn to the fire and take it out of that. (Laughter.) She was really very keen on smoke abatement, and did not care whether it was brought about by gas fires or smokeless fuel.

Mr. Williams (Gas Workers' representative), being interested in the gas industry was also naturally much interested in smoke abatement policy. He could not altogether agree with the remarks made by the lady. His experience was that doctors approved of gas fires as being cleanly and healthy. The real trouble was the ignorance that was prevailing at the present time from the

standpoint of the uses of gas. He, like the lady, came from a home where they could not afford to keep servants. His wife had not only taken charge of the home, but had brought up seven children. He could well remember the wonderful change that took place when he advised her, as nearly as possible, to do away with the open grate and to institute a gas stove for cooking and other purposes. In those days, he was a gas stoker and had to go to work at six o'clock in the morning. It was a wonderful innovation when his wife discovered she could prepare him a good meal by means of the gas stove before he went to work. Something had been said in favour of the poker, but a good housewife would see that there were no pokers handy for those who wanted to poke fires, and especially so when she came to consider the matter from the standpoint of the wages of the household in maintaining a big family. Gas could be used for a score of different purposes in the home that it was not used for at the present day. In his house, the kettle was always boiled on a gas stove, though they had to use the open fire for heating water for the bath. What he would like to suggest to the experts was that they were too modest in their advertisements, and in not sufficiently broadcasting the advantages of gas for domestic purposes. Those people who were prepared to have a " whole-gas " house should be supplied with gas at reduced terms, assistance being given in the installation of the necessary fittings. He was quite convinced that a " gas " house would be cheaper to run than an ordinary home. His neighbours sometimes said they could not understand why his gas bill was less than theirs. The secret of it was to keep the pressure of the gas on the side of the Company and not on your own. Too many people had the gas cock on full at the meter and full on at the ordinary tap. Regulate the supply of gas at the meter, instead of at the place where it is consumed. Gas could be made even cheaper than it was by advertising it and getting people to know how to use it, and thus the smoke nuisance could be remedied in a very short time.

Mr. Evan Roberts, Junr., (Chairman of the Manchester and Salford Sanitary Association) wished for advice as

to the best fuel to recommend to the public. His predecessor, Mr. Wm. Thompson, F.R.S.E., etc., decided that coke from low temperature carbonisation was far superior to the ordinary coke. Would the experts kindly tell them if the coke from low temperature carbonisation was, say, fifty per cent. better than the ordinary coke, or if it was not so good let them know it in terms? Low temperature carbonisation coke was undoubtedly far superior to coal from the smoke abatement point of view.

Alderman THOMAS GRINDLE (Eccles) knew of people who had not had their chimneys swept for more than twenty years, and he thought local authorities ought to adopt some method of compulsion. A chimney sweep should be encouraged to give a receipt when his services were requisitioned, so that if a householder was brought before the bench for committing a nuisance he would be able to produce some proof that he had endeavoured to minimise the trouble. He had been using "coalite" for the past twelve months, and had nothing but good to say of it. There was no smoke emitted, and they had a glorious fire without the necessity of using a poker, though, of course, there was no blaze. There was no soot and no cleaning out of the range at the week-end. Gas was admirable, but some of them did like to see a fire in the grate.

Mr. CHARLES E. ROSS (District Secretary, National Union of Enginemen and Firemen, Lancashire and Cheshire) said that, in order to cope with the composition of the present magisterial benches and the state of legislation, panels should be set up in the different areas for the purpose of adjudication in cases of prosecution. The material was already at hand in the shape of district regional councils in the gas industry, manned, on one side, by engineers and experts in the gas industry, and the district joint industrial councils for electricity supply, again manned by the most expert engineers in the country. If propaganda was set to work whereby those gentlemen who adorned those particular district councils could be set apart to adjudicate and judge in any particular prosecution in relation to black smoke, there would be probably a more impartial and fairer hearing and a much

better result than had been attainable up to the present. He noticed, in a discussion that had taken place, that a famous engineer stated he had lived in Manchester for twenty-five years and had never seen a fog. He wondered if that morning's atmospheric demonstration was a retribution to him. It was said that their friends at Barton Power Station had solved the smoke problem, but the inhabitants at Barton were saying that the cure was worse than the disease. He had, personally, had a niff of the invisible smoke emanating from Barton, and it was like " the old ivy that stuck to the wall." Like Limburger cheese, a little of it went a long way.

Lt.-Col. N. G. Thwaites (Director of Companies) said he was the one who put in the three dots and left out part of the quotation. It was done for the sake of brevity. In reply to Lord Gainford's letter, which was a lengthy one, he felt the *Times* would not give him more space. The quotation went on to recommend buildings on a large scale, and this was to be done at Nottingham and elsewhere. Probably, the inventor of gas, Mr. William Murdock, one hundred years ago, was faced with the same advice. In the meantime, the Gas Light and Coke Company, and many other vast concerns, had undertaken large-scale production. Mr. Goodenough had been one of the " productions " of that great industry. Col. Thwaites' complaint was that there seemed to be a controversial wish to boost one's own goods to the detriment of others, rather than discover the actual truth. He had been a member of a great many Smoke Abatement Societies in this country, and thought he might say " Coalite " had contributed towards the diminution of the smoke nuisance, and was about to do a great deal more. But, wherever he went, he found there was a disposition to neglect the poor unfortunate public. While the experts were wrangling, the public was choking with smoke. He was quite convinced sufficient oil could be produced from our coal to improve our balance of trade in the world, while unless they came to some immediate decision respecting the course to be pursued in abating smoke they would go on having miserable, rickety, children, and tuberculous people, and all the rest of the evils due to unscientific methods of using coal.

Owing to the lateness of the hour further discussion was not possible.

Mr. GOODENOUGH, in replying to the discussion, said that the way to arrive at the truth was by controversy. They had the same trouble in London with the doctors as stated by Mrs. Gee, but they had been able to convert them, and they were now the strongest advocates of gas fires. It was quite true that a gas fire cost more than a coal fire for constant use, but there was a corresponding saving in the employment of labour. If Mr. Evan Roberts would go to the Exhibition, he would find that Manchester coke at thirty-five shillings a ton made a beautiful smokeless fire, burning freely and delightfully and giving a wonderful heat. He (Mr. Goodenough) could strongly recommend the coke made by his own Corporation as giving the best solid smokeless fuel that existed at the present time.

The CHAIRMAN then moved that a cordial vote of thanks be accorded the readers of the papers, and the motion was carried by acclamation.

Eighth Session of the Conference

THURSDAY, NOVEMBER 6th, 1924.

CHAIRMAN: Ald. WILLIAM WALKER, M.I.E.E., M.Mech.E.

THE USE OF ELECTRICITY IN SMOKE ABATEMENT.

In opening the Session, the CHAIRMAN said he thought it would be agreed that electricity had done much to aid in bringing about a reduction in the amount of smoke. He had some figures which he had received that morning. They had reference to the area of the South-East Lancashire Advisory Board. In 1919 there were 295,263 kw. of plant installed; the maximum load was 185,000 kw. In 1924 the figures were: Plant installed, 460,457 kw.; maximum demand, 273,601 kw. The coal consumption in the two periods was, 1919-20, 3·112 lb. per unit generated; 1923-4, 2·190 lb. per unit generated. There was a saving of ·922 lb. per unit generated, and calculating that upon the output in the district the saving was 297,174 tons of coal per annum. The saving would be further increased during the present year, because certain large and more efficient units had been brought into operation. Taking a test quarter, the coal consumption was 2·05 lb. per unit generated. So the saving was on the upward grade.

If they were threatened with anything in this industry of theirs it was an excess of legislation. There was a Parliamentary Bill in 1919, a further Bill in 1922. Now they found that at least two of the political parties were putting in the fore-front of their programme or stunts, whichever one liked to call them, interference with electricity supply. When the arguments in favour of this interference were examined there appeared to be no authority behind them. They were founded largely upon certain figures which were given in evidence some years ago, and which had since been riddled from end to end. Yet he found that, both in coal and

power—the production of Mr. Lloyd George, or rather the production he had fathered—and also in certain publications of the Labour party, those figures were relied upon to justify further interference with and condemnation of the present organisation and authorities.

He thought it grossly unfair that, for the purposes of political propaganda by any side, an attempt should be made to deal with the industry in that way. There were people within the industry who had been carrying it on successfully for a long period of years, who were up-to-date in their ideas and methods, and who knew infinitely more of the subject than any politician. They totally disagreed with these attempts by stunt politicians to keep poking their fingers into machinery which was somewhat complicated, and of which a knowledge was required if any good were to be done. He thought those politicians would find that a strong feeling of opposition against them was being aroused. There had been enough of interference.

There were three papers to come before the Conference that afternoon, all by gentlemen eminently capable of handling the subjects they had taken. He was particularly glad that Mr. Beauchamp had been able to come, because he represented the British Electrical Development Association, which had been doing, and was likely to continue doing, so much to further the development of the uses of electricity in every form. They all owed a great debt to the British Electrical Development Association for the aid they had given to every undertaking in the country to develop and increase the domestic load.

The following paper was then read :—

How Electricity can help in Abating Industrial Smoke

By JULIUS FRITH, M.Sc., M.I.E.E., M. Cons. E.

There is no doubt that we are still suffering, especially in the North, from the curse of cheap coal. Goodness knows that the coal merchant has done his best to deliver us from this evil, but

we are conservative folk and the habits of generations are only very slowly outlived.

Coal has been, in the past, so cheap that it has not been commercially worth while to bother much about the manner of its burning, and the industrialists have been, for the most part, too intent on their own business, and too little mindful of their own and others' comfort, to care how much smoke they poured out of their chimneys.

That there have been honourable exceptions to this general condemnation must be gladly admitted, but they have been the exception, not the rule.

In a recent Government report it was estimated that the industrial power plants of this country consume on the average five pounds of coal per horse-power hour. In arriving at this average figure, the very large and very economical electric power stations which generate a horse-power hour for less than one pound of coal were of course included ; it follows that the average private power plant is much worse than this, in fact I have found in my own experience plants which consume nearer ten pounds of coal per horse-power hour.

This state of things is the result of two separate causes ; the first is that the small plant is necessarily less economical than the large one ; but this is neither all nor the worst of it, the small plant is owned by a manufacturer who specialises not in the manufacture of power but in his own trade. The production of power is to such an one merely a necessary evil, he does not understand it and often does not wish to ; he hires the cheapest man he can get to look after it, and as long as his shafting turns round would not give it another thought, but for the periodic annoyance of the smoke inspector. The management is only reminded of the existence of the furnaces by the failure of the wheels to go round, the remedy for which is to sack the stoker, if indeed that gentleman has not already seen to that by sacking the management.

Ten pounds of coal per horse-power hour means a thermal efficiency of the order of two per cent. ; that is, the energy of only two tons of coal out of every hundred burnt appears as mechanical work. Unfortunately, quite a large proportion of the loss which this involves is accounted for by fuel escaping unburnt up the chimney as smoke.

Now compare this state of things with what obtains in an electric power station. Here the managers are specialists in the production of power and what, in the private plant, is merely an annoying side line is now their entire job. Again, in the private plant the cost of coal is always only a comparatively small item in their total expenditure, and to double it even would not very

seriously alter the year's balance sheet ; whereas in the electric supply industry coal is the main item of expenditure, and to increase it by a few per cent. might make the difference between profit and loss.

All this justifies an elaboration of apparatus for economy which could not be justified on commercial grounds in a private plant. Many of these economies lie in the direction of more perfect combustion of the fuel and therefore of the elimination of smoke.

If, so far, I have carried you with me at all, you will see that the substitution of electric power generated in large and well-managed power stations, for the small and generally badly-managed private plant, would not only reduce the total amount of coal burnt to about one-tenth, but that each ton of coal would now produce only about one-tenth the smoke, making a total reduction in industrial smoke of something like 100 to 1—surely a consummation worth striving for.

After what has already been said, it would almost seem like gilding the lily to remind you of the enormous resources of quite smokeless water power still undeveloped.

If and when some feasible plan of using the energy in tidal waters is worked out, electricity provides the means of distributing this all over the country, when it could be used not only to give smokeless power to industry but to provide heat as well.

In the meantime much might be done in the way of supplying heat from fuel-burning electric generating stations. Such stations necessarily have enormous quantities of waste heat to dispose of, which heat, although fallen to too low a temperature for the performance of mechanical work, is still of immense use as heat. Mr. Pearce has had examples of this at work in Manchester for years.

For the sake of making this clearer, I have worked out the following practical example :—

Take an industrial community of, say, 10,000 inhabitants grouped into 1670 households of six members each, three of whom are working. Their houses, arranged on garden-city lines, eight or nine to the acre, and allowing for wide roads and ample open spaces, would occupy about three-quarters of a square mile. The demands for electrical energy per household would be about 6400 units per annum for those employed in the factories (1 h.p. per individual), 500 units for lighting and cooking in their homes, and 100 units for carrying the household about in trams and for public lighting ; total, 7000 units per annum per household. As there are 1670 households, the town would require a power station turning out about twelve million units per annum, which at 25 per cent. load factor would have a maximum load of a little over 5000 kw.

Suppose the station to work with a vacuum of about 20 inches, it would take about 20-lbs. of steam per unit. These 20-lbs. of steam could, on condensing, yield 20 gallons of hot water at 160° F., so that we have an average of 400 gallons of hot water per household per day. Allowing 50 gallons per day for baths and washing, 350 gallons are left for warming the house. If we allow the water to cool from 160° to 100° F. about 200,000 B.Th.U. are liberated per 24 hours, which is sufficient to keep a five-room house comfortably warm. (For those who are more familiar with electrical units this corresponds in heating effect to about $2\frac{1}{2}$ kw. for 24 hours.)

In a town of this size there are about fifteen miles of roads. To carry the hot water from the central station four 5-inch mains would suffice ; from these would radiate 2-inch mains ; and from these a $\frac{3}{4}$-inch service would supply each house.

Flow and return pipes would be provided, the flow pipes being lagged. The loss from these pipes would amount to less than 15 per cent. of the heat delivered to the houses if the lagging of the flow pipes allowed half a B.Th.U. to escape per square foot per hour per degree Fahrenheit, which would not be considered a very good steam pipe covering.

The total cost of the pipes, including lagging, excavating, laying and filling in, would cost about £45,000. The extra plant required at the central station might add another £5000. Six per cent. interest and $2\frac{1}{2}$ per cent. depreciation (21 years' life) = £4250 per annum = 1s. per week per house, which surely would gladly be paid for this service.

Due to working at a lower vacuum, the coal burnt in the central station would be increased from, say, 14,000 to 15,000 tons per annum. On the other hand, the service of hot water supply to the 1670 houses would save each householder at least six tons of coal a year, so that the community would, by adopting the hot water scheme, burn 1000 tons more coal in its central station and 10,000 tons less in its domestic grates, a net saving of 9000 tons per annum to the community, with a corresponding reduction in smoke and all its attendant evils.

But it is not only for the production of power that coal is burnt in industry. A still greater field for smoke production exists in the metallurgical processes using coal-fired furnaces. As the dwellers in the towns like Sheffield will know, these furnaces are far worse offenders than are the steam-raising plants.

It is safe to say that there is no metallurgical process for which electricity cannot be used. Some of these are still too expensive for general application and need further development, but for a great many more electric furnaces have proved themselves not only

technically but commercially superior to their old coal-burning rivals.

Conclusive tests prove that, say, for melting furnaces, less fuel is required to be burnt in the power station for the electric furnaces than that now burnt under the melting pots in the old-fashioned coke-fired type. Much has been done in Norway with electric smelting furnaces and electric melting ; reheating and annealing furnaces are largely used and are proving their worth.

Electric furnaces such as these have several very marked advantages over those burning fuel. Not only is the temperature under much better control but the fact that the furnace can be completely closed is a great advantage, as the process can be carried on in any desired atmosphere.

All these industrial applications of electric heating presuppose the direct conversion of electrical energy to heat, which process, although it can be accomplished at practically 100 per cent. efficiency, is accompanied by the disadvantages incidental to the lowering of energy down the social scale in which electricity is at the top and heat at the bottom. The process is only justified when heat is required at a fairly high temperature.

There is, however, an unlimited supply of heat in the universe, and if it is only required at a comparatively few degrees, say, above the average atmospheric temperature, a form of " heat pump " could be used in which a given quantity of electricity used in an electric motor could supply a vastly larger quantity of heat than the same quantity of electricity used in an ordinary resistance heater.

We are familiar with a heat engine as one which, taking a large quantity of heat, gives out very little mechanical work. When taken to task about it, the usual and quite correct reply is that the process, being reversible, is perfect. When reversed, the heat engine becomes the " heat pump " and can, theoretically, be used to raise large quantities of heat from the general temperature of the atmosphere to some higher temperature with a correspondingly small expenditure of power.

Mr. Edgar C. Mills (Consulting Engineer) said that Mr. Frith's paper raised an interesting point to those who were endeavouring to raise the standard of economy of engines. Mention had been made of ten lbs. per horse power hour of coal. The average coal used per horse power hour in any reasonably up-to-date works was certainly not above two, and he thought before long it would be one. This would make a difference in the 100

per cent. given by Mr. Frith, namely, ten times two as contrasted with ten times ten.

Mr. J. W. Beauchamp (Director, British Electrical Development Association) thought the allowance of 500 units for cooking insufficient.

Mr. Frith concurred.

Mr. Beauchamp suggested 1750 for cooking and 90 to 150 for lighting. The central hot-water supply was of interest but difficult. At the Swanpool Garden Village, Lincoln, it had been proposed to distribute hot water from the power station. There were to be 2000 houses, and the charge was to have been six shillings a week for all electricity for lighting, cooking, etc., and hot water. Presumably about two shillings had been allocated for hot water and the remainder for electricity. In some of the London West End flats there was a distribution of hot water from a central source at a charge of about one shilling per day, no fuel of any kind being used in the flats. Electricity at one penny per unit was supplied for all heating, lighting and cooking, the tenants, fairly well-to-do people, were satisfied, and had practically an automatic home.

Mr. Frith said that the average figure of five pounds of coal per horse power hour was taken from a Government report and was probably fairly accurate. If in that average was included the very largest stations of the highest efficiency, working with less than one pound of coal per horse power hour, there must be many small stations taking somewhere about ten pounds in order to make up the average of five. It was very satisfactory to learn that Mr. Beauchamp was going to put up the consumption per household for heating and cooking from 500 to 1500 units per annum. The one shilling per day mentioned by Mr. Beauchamp for hot water should pay very well ; it could, he thought, be done for very much less. The figure of one shilling a week mentioned in the paper included a profit of six per cent. on the capital and a suitable depreciation fund. Hot water distribution from central stations had been put into practice in America, and there was at any rate one example in this country of distributing waste heat from a big electric station, namely, in Manchester.

The following paper was then read :—

The Influence of Electricity on the Domestic Smoke Problem

by J. W. Beauchamp, M.I.E.E., Director and Secretary, the British Electrical Development Association.

Although the influence of electricity on the industrial smoke nuisance cannot be dealt with in this paper, yet the spread of electrification in the world of work has some bearing upon the home problem.

The Manchester Electricity Supply Department, I believe, claims in ten years to have put out of action some three hundred industrial chimney stacks. Salford recently reported 40,000 h.p. electric motors operating in thirty-three different trades.

In America the electricity supply undertakings have already discovered that for highest efficiency and lowest cost the load upon the works must not only be large, but be well balanced ; wide use of electricity from the same system for lighting, cooking, heating, and power conduces to the lowest rates for all classes of consumers.

Working men and women to-day are accustomed to the use of electricity in factories for lighting, often for canteen cookery, and almost always for machinery driving. They have seen the evolution of special machines and processes, many of which would have been impossible without the use of electric power, and the more thoughtful of them are already asking why more of the advantages of this form of energy cannot be made available in their own homes.

In the work of improving conditions under which heat energy is used in the home, and so covering a solution of the domestic smoke problem, the electrical industry is running parallel with the gas industry. Naturally, we hold the view that we provide a more complete solution to the problem. In the meantime the competition between these two great public services is to the benefit of the public, and it is to be doubted if without that competition the inventor and manufacturer would have made anything like the progress which the past few years have seen.

In the opinion of the writer, the electrical people have not so far in any general way, and with certain brilliant exceptions, shown a grasp of the essentials for making the most of their business in the way that the gas undertakings have done.

Public services of heat energy are peculiar in this respect, that the consumer has more to do than merely to obtain the

connection or service ; he requires appliances, less permanent and more complicated than those needed for the use of water, appliances which require a certain amount of attention to keep in a proper state of efficiency, and some degree of knowledge and intelligence in their use. In addition, we find in both gas and electricity services that the consumer, who after all does not want gas or electricity but the services they render, has to rely upon the assistance of at least three groups within the industry concerned.

1. He wants a continuous service of gas or electricity as cheaply as he can get it.
2. He wants appliances for its conversion into light, heat or power.
3. He wants the " installation " piping, cabling and connecting up, maintenance and repair.

The gas industry is much older than ours, and in most cases has developed a closer supervision over these three activities. Upon this joint working for the good service of the consumer success depends, even more than upon price ; and the work of the inventor and manufacturer, the local business of the installation contractor, and the sales policy of the gas or electricity undertakings, need to be closely co-ordinated if the best results are to be attained. Many gas undertakings provide brilliant examples of this co-ordination, and to-day the electrical industry is steadily and in some places even rapidly approaching a similar standard.

In the past, however, and in many instances to-day, this close connection has not existed, the electricity supplier thinking only of his consumer in relation to the electricity used and paid for, and the contractor or manufacturer often enough pushing all sorts of appliances and proposals without proper regard to the supply conditions in different districts.

In no other business has the word " Service " so pregnant a meaning, and this is increasingly true as one tackles domestic work. The consumer and consumer's servants have to be instructed tactfully, and by people with a sympathetic knowledge of home conditions. They must be provided with the more expensive items of apparatus on hire or hire-purchase, watched unobtrusively from time to time to see that they are getting the best value out of the method, and supplied with the prime mover, in our case electricity, at reasonable rates, not necessarily cut rates, but certainly on tariffs or charging systems, essentially simple, and not hedged round with scientific trimmings as too often in the past has been the case.

Domestic Lighting is perhaps outside the scope of this paper ; since we passed the day of the torch, no form of artificial lighting can really be accused of making much smoke. We may, however, claim for electricity that it offers a light which is without any effect upon the atmosphere, taking nothing from it and adding nothing to it.

Heating and Cooking.

The open fire we probably have to live with for a long time to come, yet, improvement in the design of grates has done much already to reduce the domestic smoke nuisance. The wide use of the now popular Radiant electric fire is helping also to a large extent by replacing the " short hour " coal fire, the fire lighted to minister to someone's comfort for one hour or less and often taking half an hour to burn into a radiant and smokeless condition, not only wasteful but a cause of labour, smoke and dirt out of all proportion to the benefit derived from it. During the half seasons and in cold summers the electric fire is very largely used, and may already be credited with a good share in reducing domestic smoke.

In cookery the progress so far made by electricity is less, but rapid at the present time. Any electric or gas apparatus which puts the coal range right out of action is a big smoke reducer. Most ranges are stoked very frequently when in action, and generally forced first thing in the morning to get hot water ; fed as they are from the top, they do produce a great deal of smoke until the whole range is hot and working steadily.

We have now in many places all-electric kitchens, or combinations of coke or gas and electricity, or all three, giving the householder separate appliances for the water heating and the cooking, and so reducing the time and conditions of imperfect fuel combustion which produce smoke, the forcing of fires under strong draught in massive ranges of cold iron and brick with the object of heating large quantities of water quickly, or raising to cooking temperature an oven and structure the mass of which is out of all proportion to the food to be prepared.

The dearness of coal is a blessing, if a disguised one ; it has probably changed methods even in cities like Manchester. The writer remembers in earlier days the open roaring fires, with the raised cupboard oven, and the cast-iron kettles and frying pans with walls nearly half an inch thick ; to-day we are able to use an immense variety of utensils in the thinnest metal, and in sizes and shapes to avoid waste, and in many electrical appliances the heat is actually released within the vessel or body of the liquid being heated.

We have been told for thirty years that electric cookery could never be an economic proposition, but the effort of the engineers to apply a relatively expensive form of heat energy to this important work has not only been successful, but has forced upon them so close a study of the use of heat that their work has had a good influence on the design of all cooking and heating appliances, and is now beginning to affect even the working methods of the conservative housewife and chef.

In short, the electric method teaches us not only to use heat efficiently but to do with less of it by alteration in method ; the air-tight electric oven, capable of roasting meat with one-fifth to one-eighth of a unit of electricity per pound weight, is an example ; the heat may be of a finer or dearer texture, so to speak, but it acts inside the oven close to the meat, and very little of it is lost. As a striking example of this local application of heat for which the electric method is distinguished, consider electric welding ; here metal parts are joined together by heat actually evolved in the metal at the point of juncture, a striking comparison with the older ways of the smith and his forge.

So far electric cookery apparatus, at least the range, has evolved on lines similar to gas apparatus, even as that evolved out of the coal fire cookers which preceded it ; as usual, a compromise, something better but not too much unlike the appliances which it replaced.

With our method, however, there is more room for departure from existing ways of cooking food, and slowly kitchen methods will change and take the fullest advantage of the ease of direct heat application, and of the facility for dividing up heat applications to cookery, which electricity affords. When we consider the very small amount of heat energy which is really absorbed by a given quantity of raw food to bring about the physical and chemical changes which make the difference between raw and cooked, it is obvious that there is room for great progress yet, and that progress will probably be easier with electricity than with any other medium.

Already progress has been made in heat storage cookery, "haybox" and similar devices, but there is little "internationalism" amongst cooks or in the manner of serving food. Each country has its methods, the kitchens and the stomachs have grown up together, so to speak, and the reformer may find it easier to mould the religious or political opinions of a people than to make them eat stew when they have been reared on roast.

Perhaps, in future, the coal, gas and electric methods of individual cookery will be in competition with mass cookery

and the distribution of hot food. This sort of thing is happening to-day on a small scale in service flats, canteens and restaurants.

The writer ventures to hope this will not be the solution, that it will rather lie in the scattering of individual dwellings, the opening out of cities, and the distribution by electricity of light and heat, perhaps supplemented by some smokeless fuel, and power for production and transport.

Home Heating.

Now, although we are all to some small degree reducing domestic smoke, we are not reducing chimneys ; so far very little change has taken place in house design to suit the newer methods of lighting and heating.

The architect to-day has a kindly feeling for chimneys and often he weaves them into his designs with skill, but when we can assure him that the last chimney has gone cold, his imagination will take a leap, providing roof gardens and other features of beauty, and we may for the first time become familiar with those "Tilescapes" at present only enjoyed by airmen and cats.

In new houses, costing, for structure only, from £750 to £1500, some 3 to 5 per cent. can be saved by omitting chimneys from bed and other rooms where continuous artificial heating in winter is not needed, thus saving on building material and labour for features seldom used on account of the trouble involved ; this will pay for the electrical equipment to replace them, and offer the occupant something he can use with comfort and satisfaction. Architects seem to be anticipating changes so far as coal cellars are concerned, they get smaller, the wash copper also is often left out.

In the kitchen the use of an electric range gives more freedom in planning. The position of the coal range is often fixed by consideration for the chimney stack, whereas the electric can stand in a good daylight and be adjacent to dresser or sink, no small matter to those who work in the kitchen year in and year out.

Change in methods of water heating may also have a bearing on design. The electric heat storage method points to subdivision of hot water supplies about the house, separate tanks for sink, baths, etc., cutting out all the wasteful hot water distribution and leaving only cold water pipes and electric wires to consider.

Generally, the engineering equipment of the house has developed, and it is to develop so much more, that the time seems at hand to consider the design of structures in relation to the

equipment. It is still all the other way, and even in a well-found house the latest appliances of the gas and the electrical engineer often look like excresences for which the architect had no great welcome.

The problem of home heating will probably be found less simple than the mere substitution of one form of heat energy for another—gas for coal, electricity for gas—and it will be solved rather by a study of fresh methods of keeping the heat losses from the human body within the limits required for health and comfort.

So far we have no general practical way of portable heating, excluding the special work done in this direction for airmen ; we have not yet produced any body-heating appliance which we can carry about with us all the time, and must, in the open air, rely upon clothing or " lagging " to retain the natural heat of the body.

Indoors we achieve the desired effect partly by rad ant heat and more extensively by trying to keep the air temperature above the outside level ; in short, by raising a room and its contained air to a temperature which may in winter be 30° F. above its surroundings, and then releasing into it continually enough heat energy to make up losses arising from leaks and ventilation and the conductivity of the structure.

We are apt to think that primitive people relied entirely upon radiant heat, the sun or some open fire, but in the earliest dwellings one sometimes finds an example of efficient and extremely economical convective heating. I refer to the arrangement where the cattle were housed during the winter in a sort of basement over which the owners lived. The people entered by going up some few steps, and so the dwelling or sleeping place was above the source of heat, giving them, with the exception of the crannies which must have amply provided for ventilation, a sort of diving bell or warm air pocket in which to rest, and there may yet be a hint in this method for the architect and the heating engineer.

Recently, the papers have referred at some length to the discovery of Roman ruins, in which the rooms were heated by a furnace under the floor, and they evidently had seized one important principle, that comfort comes from a higher temperature around the feet than around the head.

In the last few years much attention has been directed to the value of artificial heat in radiant form, the desirability of living

and working in an air temperature relatively low, and obtaining the additional heat necessary by radiation from bright fires of coal, gas or electricity. In the writer's opinion there has been a tendency to overwork this idea. Artificial heat requirements vary so much with constitution, with the nature of one's occupation, and to some extent with temperament, besides depending a good deal on the moisture or dryness of the air.

It does appear that for most people a mixture of radiant and convective heat would be the most satisfactory, an ambient temperature something a little below the line of comfort perhaps, supplemented by bright and cheerful sources of radiant heat. In this connection the work of Dr. Margaret Fishenden is of great interest and probably familiar to many here.

Latterly, a good deal of attention has again been directed to the combination of heat and light, the so-called Sun Ray heating, in which high temperature filaments giving off short wave length radiation, and shielded from the eye, are used to warm the body or floor surfaces and coverings, and at the same time spread a good deal of cheerful and stimulating light.

Obviously, the subject of artificial heating is of vast importance and will repay study. It closely touches the smoke problem. In the average middle class house, well-built, furnished and used in such a way that heat losses are not great, we are still burning $2\frac{1}{2}$ to 3 lbs. of good coal per hour for perhaps twelve or sixteen hours a day in winter, and in order to maintain comfortable conditions for two or three persons in one room.

In this city, Manchester, you have the advantage of very simple tariffs and low rates for electricity used in the home. A small annual charge based upon rateable value, and in itself generally not greater than the usual expenditure on the electric lighting alone, enables you to purchase electrical energy for every purpose at the present time, I believe, at a halfpenny per unit, through a single meter, permitting a simple installation of wiring, and the use of small electrical appliances for heating or labour saving in any part of the house, in addition of course to fires and cooking ranges.

This method of charging is spreading rapidly throughout the country, and in many districts it is found that houses, still relying perhaps on coal for their heaviest heating work, are now able to do all of their cooking and some of their heating, much labour saving and all lighting, for an addition of perhaps 50 to 75 per cent. to the amount which they have been in the habit of paying for electric lighting alone.

A middle class family of five persons will carry out the usual cookery with an electric range for one unit of electricity per head per day ; say, 36 units per week at a halfpenny per unit, 1s. 6d.

Your tariffs, together with the great profits earned by the undertaking, show what can be done under keen management with modern generating plant, and a very big output of " mixed " load—lighting, factory power, transport and domestic heating.

If some consumers are able to do this, why not all ? Neither cost nor quality of the cookery can be against the method.

The answer is that to make the use of electricity general in the land a low rate alone is insufficient. Several other considerations have to be grappled with in an ungrudging and long-sighted manner.

When we should talk ironmongery we talk amperes, and so far very little real advertising has been done. The immediate essentials are :—

Firstly, " Service " to the Consumer.

A.—Clear and simple advertising.

B.—Plenty of actual demonstration in use.

C.—Hire or easy terms for the appliances and wiring.

D.—Tactful inspection and proper maintenance in use.

E.—A reasonable rate for electricity and a simple tariff system.

Lastly, " Service " to the Consumer.

The message to-day of the electrical industry to the householder is based upon a mixture of raw fuel and electricity. The raw fuel to be good coal, coke or smokeless fuel, consumed in one or two grates or furnaces in each house and employed for the heavy work of water and room heating, so reducing to a minimum the labour attendant upon the use of fires, the storage and cartage of fuel and the emission of smoke and grit ; beyond this, to rely upon electricity for short period heating, cookery of food, lighting and labour saving by electrically-driven machines.

These proposals are being carried out where the rates for electricity are suitable ; where less suitable, the exact economic mixture depends upon circumstances and the house owner's views, whether he thinks it is worth while to pay a little more for cleanliness and comfort, and so on.

The differences in electricity conditions up and down the country make it difficult to generalise, as people so frequently do, on the dearness or cheapness of the electric method. We contend, and I think properly, that we need not offer the electric service at the same price as gas or raw fuel, it is worth something more ; but I am aware that the factor by which you may multiply it is a variable one. When you offer a person something better than he has had, you can never get from him the full value of the betterment. To do business each side must gain something. Also, there is a great difference of opinion amongst people as to the value of improved home conditions. The truly thrifty may be willing to spend more than those whose ideas of economy are limited to reducing bills. However, generally speaking, it is obvious that the cost of electric service to the user is " falling " whilst its advantages are rising. The fitments and furnishings of houses do not get cheaper, labour does not become easier, and it is more and more a case for cutting out work, lengthening the life of goods, and arranging one's affairs so that toil, drudgery, danger and delay are reduced wherever possible.

It is difficult to overestimate the value of any work being done to reduce the smoke nuisance ; its success means more than the clearing of the atmosphere, for in a general way smoke reduction indicates increase in the efficiency of use of heat energy, a vital matter to people who are always drawing upon reserves of fuel which cannot be replaced, and may live to see the day when waste of heat will be more reprehensible than waste of bread.

It has been stated by some experts that some six per cent. of the weight of coal burnt in domestic grates falls back in the form of soot. It is interesting to speculate upon this, bearing in mind the total weight of coal which has been destroyed in the domestic grate since we started using that form of fuel. We must be making the world lighter in weight and larger in diameter —a point which we may commend to the attention of the astronomers !

Mr. C. H. Rayner (Electricity Department, Manchester Corporation) said they were always being told about the wonderful things that were being done in America, and that there were so many thousands there as compared with hundreds here who used electricity. Well, they must stick up for the old country. In America, many of the towns were of mushroom growth and required heat, power and light immediately, and for them it was much more cheaply obtained by electricity than by other means. Quite a different state of things obtained in an old-established country

like England, where even yet oil lamps provided illumination in our villages. This accounted, in a great measure, for the difference in the number of units per head of population sold in America as compared with this country. He would appeal to the manufacturers of electrical apparatus to reduce their prices. Electrical undertakings were doing their share in supplying current at cheap rates, but when one came to enquire the price of an electrical radiator, the cost being round about six or seven pounds, the public would not purchase. A gas boiler could be obtained for a couple of pounds, but an electrical boiler could not be purchased for less than seven or eight pounds. If the price of electrical apparatus could be reduced, the use of electricity for heating and cooking would make very great strides.

Mrs. Higgs (member of the Council) thought that every housewife would prefer to have electricity in the house except for one terror, the fusing of the wires. This was a very real terror to women. If there was anything the matter with the gas one could get a tallow candle, stop the leak, and turn the gas off, but if fire broke out one did not know what to do. You were told that sand would solve the problem, but you did not usually have sand in the house. The difficulty had occurred in a house belonging to the speaker. A wire fused, and the person who was in charge of the house ran out into the street calling out "fire," while an uninstructed millhand girl who was serving in the house "happened to do something" that stopped the house burning down to the ground. She had been told that, in a climate like Oldham where there was a considerable amount of damp, an electric wire that was not properly protected might cause fire. A friend of hers had her house burned down to the ground. She was away on holiday at Portishead, near Bristol, at the time, and on her return she was homeless. Women did not understand "amperes" but they did understand gas. Electricity was certainly superior to gas in one respect. Over and over again she had had to send for three sets of men to attend to the gas supply. The gas was not burning brightly. A man came and said it was burning all right. Then the meter man was sent for. The meter was all right. Then an outside man was sent for who dug up the garden

to find out about the choking of the pipes outside. She had had this experience twice in three years. Gas blackened the ceilings and made the rooms dirty. It was only natural that a housewife would prefer something likely to be less troublesome than gas. On the other hand, considerable cost had to be incurred in regard to a supply of electricity.

Colonel McConnel said that perhaps he might be considered to be something of an electric lighting enthusiast when he stated that he put in one of the earliest installations in a mill nearly forty years ago. He happened to be the trustee of an estate, and some years ago he electrified every cottage from water power. The people were all delighted, and the result was thirty per cent. profit. ("Shame.") There were no accumulators. When darkness set in, the turbine was turned on and the whole village was illuminated. At ten o'clock, when it was thought everybody ought to go to bed, the lights went out. In the morning, the mill bell rang at five o'clock—time to get up— the whole village, yards, streets and everything else were brilliantly illuminated. The people were cheered up when they went to their work. It might be said that this was a little despotic, but it was greatly appreciated by everyone. For the last two years he had been trying to do away with the smoke nuisance as far as his own house was concerned. Not a pound of coal had been burned during that time. Central heating had been installed, coke being used for the boiler. There were gas fires or electric radiators in every room. No trouble was experienced with the cooks, who were quite in favour of electric cooking. There was never any complaint that the flue was out of order or that the water wouldn't get hot. A great deal more propaganda by advertising should be undertaken. Even when they went to the Exhibition, what did they see ? Radiators were put in the wrong place, and the chimney breast made up so that the heat went up the chimney instead of into the room. The proper position of an electric radiator was not in the fire place but in the centre of the room or by the armchair. If municipal authorities could see their way to allow the public to rent expensive apparatus at a cheap rate good

profit would certainly result and the use of electricity be greatly popularised.

Mr. Evan Roberts, Junr., (Chairman of the Manchester and Salford Sanitary Association) found that many people had difficulty in deciding which was the best electric radiator. Even in the showroom of the Manchester Corporation Electricity Committee one could not learn which was the most economical or best type. It did not appear to be regarded as coming within the province of the Committee to recommend any particular radiator. He agreed that the high cost of electrical apparatus militated against its general adoption, and that was the reason why some years ago he had not wired a large number of houses. He knew that he had stated that afternoon, at any rate it had been taken for granted, and stated at the meetings, that domestic fires were the greatest offenders in regard to smoke pollution. He had used that argument because it had been so stated by experts at the present meetings, but in some districts he knew the factories and works chimneys were undoubtedly the greatest offenders, especially where there was careless stoking. The average household consumed two to three hundredweights each week, taking the maximum figures it came to about seven tons of coal a year. He knew of one factory which was consuming 5000 tons a year, or more than the quantity consumed by 700 dwelling houses. Personally, he considered that the greater use of electricity would solve the smoke problem.

Mr. H. G. Clinch (Halifax) said he had heard some very bitter remarks respecting the emission of smoke from electricity generating stations. In April, 1923, the Halifax Electricity Works were probably among the dirtiest, dense clouds of very heavy, black smoke were being emitted practically all through the day. The cost of generation at that time was 0·24d. per unit. The works were now probably the cleanest in the country, and in August, 1924, the cost of fuel per unit was 0·205d.; September, 0·19d.; October, 0·18d. This result had been brought about by constant supervision and by careful education of all the staff by the boiler house superintendent, who had co-operated

with him in his efforts, and who was his friend instead of being his enemy, which was as it should be.

Mr. E. C. MILLS (Consulting Engineer) said that one reason why the open stove was popular in this country was because it ventilated the room. Similarly, a well-fitted gas stove ventilated excellently. But this was not so with an electric heater. It behoved the electrician to provide some satisfactory method of accomplishing this important function.

The CHAIRMAN said that before electric radiators were exhibited in the Manchester Corporation Showrooms they were thoroughly examined and tested for reliability. Therefore, they could not recommend any particular make more than another. It was up to the individual buyer to select the stove which best suited the furniture and arrangements generally of his rooms. He was very much surprised to hear the remarks of their lady friend regarding the fusing of wires, which was a thing which seldom happened. Probably what was meant was the blowing of the fuse, which could be remedied in a few moments by anyone. No profits were now made by the Manchester Corporation Electricity Department. The moment a profit was shown on the balance for the year, the cost was reduced to the consumer.

Mr. J. W. BEAUCHAMP, referring to Mr. Rayner's remark about the extent of electrification in America, said that although much of the energy was generated by water power it was not necessarily cheap, but the supply of electricity was accompanied by an intensity of salesmanship which could hardly be credited in this country. Also, as Mr. Rayner remarked, many towns had nothing but electricity. The lady who had expressed alarm about "fusing" would have no trouble if she placed her wiring orders with reliable contractors. The blowing of a fuse was generally an indication of a fault somewhere ; the fault remedied, putting back the fuse was a safe and simple matter. He agreed that such terms as "ampere" were not informative to the public, and phraseology should be simple. Reliable pamphlets giving costs and other electrical information in popular language were

now circulated by an independent body. He referred to an article in the *Electrical Times* by Dr. Lulofs, of Amsterdam, on the use and placing of electric fires and heaters. The ventilation of rooms was an important point, and to be considered with the architects. Considerable saving could now be effected, but omitting many chimneys. Hand-control ventilators could be provided, with fresh air inlets at the bottom and exits at the top of rooms. The open fire certainly did ventilate well, but at a price we could not always pay.

Dr. Margaret Fishenden said that one great advantage of the electric radiator was that it could be placed exactly where it was required. No one seemed to have the courage to state the exact merits of different radiators. The point was that all radiators had about 107 efficiency. The best kind of electric radiator depended entirely upon the circumstances. One could have a radiator or electric heater up to, probably, about 80 per cent. radiation, but all electric radiators were equally efficient, though they produced their heat in different forms. The problem of smokeless heating was most difficult in connection with the small house, because all its needs must be fulfilled by one coke fire.

The following paper was then read :—

Power from Sources other than Coal

by Professor Miles Walker, M.A., D.Sc.

It has been quite rightly pointed out that so long as coal is our main source of heat and energy we should try to burn it in as cleanly a manner and as economically as possible. The large electric generating stations driven either by the direct burning of coal, or by products of coal distillation, are very much more efficient and cleanly than the old-fashioned methods, and without a doubt in the immediate future the modern electric generating stations are going to do splendid work in the reduction of smoke in our big cities.

We look forward, however, to the time when we shall get a great deal of energy from sources other than coal. There are two main reasons why we should do so. In the first place the world's stock of coal is not inexhaustible. It is our duty to conserve it for other uses in which it is indispensable. What

would we say to-day if the coal era had arrived four hundred years earlier in this country, and if the inhabitants of England from the reign of Henry VIII. and onwards had burned up nearly all the coal and left us very little with which to smelt our ores? Should we not have put them down as greedy wasteful ignoramuses?

In the second place, whatever method is adopted of burning fuel the products of combustion destroy the purity of the atmosphere and spoil the beauty of the countryside.

The great cleanliness and freedom from obnoxious gases noticeable in many of the industrial areas in Switzerland, Norway and Sweden make us envious of the great water powers which have been developed in those countries.

It is said that Britain has not very much water power that can be economically developed. According to the Report of the Water Power Resources Committee, the possible outputs from the *inland* water powers that could be economically developed amount to :—

	Kilowatts.
England	20,440
Wales	35,900
Scotland	195,000
Total	251,340

The output from coal-fired electricity stations in Great Britain in the year ending March 31st, 1922, was 4955 million units, representing a continuous equivalent output of 570,000 kw.

In England the inland water power, even if fully developed, would not yield more than one-half per cent. of the total power required. Taking England, Wales and Scotland together, the inland water powers could not provide one-half of the electric power at present used.

But, if we bring into consideration the power of the tides in our estuaries (leaving out of account for the moment the economical considerations, to which I shall refer directly), we find that the power which could be made available is very much greater than the whole of the power at present generated in the British Isles.

Last year there was published a most interesting and instructive book, called "Studies in Tidal Power," by Norman Davey (Constable). In this work is a very full treatise on the theory and economy of tidal power utilisation. The author presents the main facts clearly and brings before the reader the many difficulties that present themselves. He is most careful

not to overstate the case in favour of tide utilisation. He gives maps of the main estuaries around our coasts where tidal power might be used, and calculates the mean power available at each place. On a conservative estimate he shows that the power in English estuaries that might be available, if the capital to develop it were forthcoming, amounts to no less than the equivalent of 850,000 kw. continuous. In this estimate the efficiency of conversion is taken at 40 per cent.

The Severn Tidal Power Scheme is considered in detail, and the estimate of the proposers of the scheme as to the amount of power available, namely 208,000 horse power (or 500,000 for ten hours a day) is confirmed. The cost of the Severn scheme estimated at post-war prices is about twenty-eight millions, of which £2,200,000 was for a rail and road bridge, which are in themselves desirable features, and not less than sixteen millions was for electrical machinery. The hydro-electric work on the estuary is estimated at only seven millions and the storage reservoir at two and a half millions. It is probable that at the present prices the total capital expenditure could be considerably reduced, but even at these figures it would be worth while to carry out the undertaking. Taking interest on capital at six per cent., maintenance and depreciation of hydraulic work at $2\frac{1}{2}$ per cent., maintenance and depreciation of machinery at $7\frac{1}{2}$ per cent., and working expenses at 10 per cent. of the total expenditure, the cost of power works out at 0·62 penny per unit. The cost of a transmission line to London would be about £1,250,000. The interest on this capital sum would increase this per Board of Trade unit by about 0·22 penny.

The estimated cost of this scheme was enormously increased by the adoption of a double electrical conversion, thought to be necessary owing to the fact that the storage reservoir would be about eight miles from the primary turbines. In my opinion, however, it will be possible to devise a system in which the water for the storage reservoir is pumped directly through water mains at the estuary, and this will cut down the cost of electrical machinery to less than one-half.

We see from these figures that the scheme does not offer such a high rate of interest as to attract an ordinary investor, especially as a certain amount of risk is involved. But a great economical scheme should not be held up from commercial considerations of this kind. We have in England at the present time so much labour going to waste, so much money being paid out in doles, and so many iron furnaces shut down, that it is penny wise pound foolish to haggle about the rate of interest that a tidal power scheme would pay the investor. What rate of interest do we get on the money paid out in doles? Here is a national asset of 200,000 horse power going to waste. We have all the

material and all the labour in the country for carrying out the scheme and making it successful. Let us get to work and do it, and the country will then possess a valuable asset, instead of a great army of degenerated unemployed, pauperised by the dole and idleness.

An engineer travelling in Holland might ask the question : Where did the capital come from to build the thousands of windmills, and how much interest do you get on it ? Because it is well known that the capital cost of a windmill in proportion to the average power developed is so high that the investor does not look upon it ordinarily as a proposition that is worth while.

If the Dutchmen in the past had sat down to calculate the capital cost of their windmills and the interest they would get, there would be under water in Holland to-day many thousands of acres which now produce the finest agricultural produce. Instead of sitting down and doing nothing the Dutchman got to work and built the windmills. It only cost him effort, and now he has this splendid return.

This matter of the utilisation of the tides is one in which the Smoke Abatement League should take the very greatest interest.

One of the main reasons why we wish to get rid of smoke is that we wish to get more sunshine. Now smoke, though a very serious cause of our want of sunshine in towns, is by no means the worst screen that we have between Britons and life-giving sunshine. The greater part of the year clouds and water vapour come between us and the sun. It might be quite a good plan to form an off-shoot from our League, called the Cloud Abatement League, or perhaps better the Cloud Control League, for clouds are very valuable and could be made more so if properly controlled.

Physical science has not yet advanced so far that we can clear away the clouds in the sky at will, but I am convinced that future generations will be able to do so, for the following reasons. A cloud consists of small particles of water which are so finely divided that they remain suspended in the air. These drops are water, not vapour, so that we do not require great supplies of negative heat to condense the moisture. We only require some means of making the particles coalesce. This can already be done on a small scale, and the amount of energy required to bring about the precipitation of a large cloud is small in comparison to the energy that can be obtained from the raindrops as they fall. It would be worth while to devote large sums of money to research upon this matter, especially in this country, as the success of our greatest industry, agriculture, is so greatly dependent on the weather. If we could give the farmer rain when he wished it, and sunshine when he wished it, this country would be able

to produce a very much larger proportion of the food required for its people.

But you may ask—What has this got to do with power from other sources than coal? Let us consider the matter first of all shorn of all the practical difficulties. The average rainfall for the British Isles is about 26·5 inches per annum. We may assume that this rain falls an average distance of 1200 feet. It is a simple matter to calculate that this rain, falling through this distance, represents 28,000,000 horse power, taken continuously throughout the year. Even if only one-hundredth part of this power could be made available we would have a power equal to about half of the total electrical power at present generated by the burning of coal in this country.

Now is it possible to utilise the energy of falling rain to generate electric power? Looking at the matter again purely from the theoretical point of view, unhampered by practical considerations, the energy of a falling raindrop should be capable of being transformed into electrical energy in a very efficient manner. Let us suppose in the first place that we have solved the problem of making the cloud particles coalesce into falling raindrops. That is a problem in itself, which, I think, will undoubtedly be solved some day. Whether we see it in our time or not depends upon how soon we actively attack the problem. We might proceed to deal with the great cloud banks blowing over from the south-west in the following manner. Suppose stretching over a great area, such, for instance, as the sand flats near the mouth of the Mersey, there might be erected a large conducting surface, supported on insulators, capable of withstanding a pressure of 1,000,000 volts or more. In the upper regions of the air we must imagine our apparatus for creating raindrops from the drifting clouds. Each raindrop could be charged with electricity, say, positively, and in falling upon the immense charged surface beneath, the potential of its charge would be raised to that of the charged surface, which might be at one million volts. By almost balancing the gravitational attraction by an electrostatic repulsion, a considerable fraction of the energy of the falling drop could be converted into electrical energy. In the footnote below some figures are given which show that from the point of view of insulation and dielectric strength of air there is nothing impossible in the method.*

* Let us take each drop as having a volume of one millimetre cube. To give it a charge of one electrostatic unit would require a pressure of about 6000 volts. Suppose that the large charged surface creates an electrostatic field having unit strength, so that the force upon the unit charge would be just less than its weight. A unit field is 300 volts per centimetre, or about 10,000 volts per foot. This is well within the dielectric strength of air. One might even use, if necessary, a field five times as strong and rely upon the kinetic energy of the particle of falling rain to force the drop on to the charged surface.

If one could cause a very heavy precipitation of rain at any required place, one might convert into electrical power the potential energy of a great fraction of the clouds that come over from the Atlantic, and which in fair weather pass over the country without precipitation. Thus in wet seasons one could have clear skies on the leeward side of the apparatus, and in times of drought the apparatus could be used for bringing down any available moisture. We could thus enjoy sunshine for the greater part of the year and have sufficient rain for the requirements of the land.

The control of the sunshine in this way would then bring to our consideration the utilisation of another source of power, namely, the radiant heat of the sun. Radiant heat and light from the sun falling upon one acre of ground is equivalent to 7000 horse power. In sunny countries the sun's rays have already been used for the generation of steam, and although the method is extremely inefficient it has been found to be worth while where fuel is scarce. The day will undoubtedly come when this radiant energy will be converted in a much more economical manner. There are two reasons for believing this. In the first place, the temperature of the source being extremely high the possible thermodynamic efficiency is very high. In the second place, the energy already exists in an electrical form, and it may not be necessary to convert it into heat at all. We may some day find a method of reducing the frequency of the electric wave, which at present is inconveniently high, to a frequency more suited to our electrical apparatus.

The suggestions made in this paper are at present very far from practical solution. The stores of energy are so great that it is well to do something more than merely keep them in mind.

A vote of thanks was unanimously accorded the readers of the papers.

Ninth Session of the Conference

THURSDAY, NOVEMBER 6th, 1924

A popular Lecture was given by Ex-Bailie W. B. SMITH, O.B.E., Glasgow, entitled, "The Cost of a Smoky Atmosphere," with lantern slide illustrations.

J. F. Tangye, Printer
Manchester

1926

REPORT of the SMOKE ABATEMENT CONFERENCE

HELD AT BINGLEY HALL
BIRMINGHAM
September 7th–10th . 1926

SMOKE ABATEMENT LEAGUE

OF

GREAT BRITAIN

REPORT

OF THE

Smoke Abatement Conference

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BINGLEY HALL, BIRMINGHAM

September 7th, 8th, and 9th - 1926

"SMOKE"

A

SMOKE ABATEMENT LEAGUE
of GREAT BRITAIN

FOUNDED 1909.

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Local Authorities Affiliated to the League :

Berwick-on-Tweed, Birmingham, Blackburn, Bolton, Bootle, Brighton, Bristol, Burnley, Bury, Buxton, Cardiff, Chester, Chesterfield, Darlington, Ealing, East Retford, Eccles, Edinburgh, Failsworth, Farnworth, Halifax, Harrogate, Huddersfield, Hull, Hyde, Irlam, Leeds, Leicester, Lincoln, Liverpool, Manchester, Mansfield, Newcastle-on-Tyne, Nottingham, Norwich, Oldham, Preston, Richmond, Rochdale, Rotherham, Salford, Smethwick, Sheffield, Stalybridge, Stirling, Stoke-on-Trent, Stretford, Sunderland, Wakefield, Wallasey, Walsall, Widnes, Wolverhampton, Worcester, Wrexham, York.

Institutions and Societies Affiliated to the League :

Beautiful Oldham Society, British Medical Association, Dental Association, Institution of Electrical Engineers, Institution of Gas Engineers, Institution of Heating and Ventilating Engineers, Sheffield Federated Health Association, Society of Medical Officers of Health.

INDEX

THE SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN is concerned with the problem of air pollution which is mainly caused by smoke. The aims of the League are :—

(1) To create an informed public opinion on the evils of air pollution.

(2) To promote or support legislation for preventing the smoke nuisance.

(3) To enquire into, and if thought advisable, assist investigation directed towards the abolition of smoke, whether industrial or domestic.

(4) To take steps to popularise the use of smokeless methods of heat and power production.

The Smoke Abatement League of Great Britain was founded on September 15th, 1909, at a special meeting of Local Authorities and other bodies, held in the Town Hall, Sheffield, and called together by the Rt. Hon. Lord Mayor of Sheffield, Ald. H. K. Stephenson.

The Glasgow and South-West Scotland Branch was instituted on February 2nd, 1910.

The Manchester Branch was revived in 1926.

Opening Session of the Conference

INDUSTRY *and* SMOKE ABATEMENT

TUESDAY, SEPTEMBER 7th, 1926.

HELD IN THE

CONFERENCE ROOM, BINGLEY HALL.

Chairman: Councillor WILL MELLAND, J.P., Chairman, Smoke Abatement League.

Councillor MELLAND, in opening the proceedings, said it was rather a curious thing that in the past there had always been discussion about their aims and ideals, but the question of policy had never been discussed and had never been laid down as such. The particular question that he wanted to open up had been discussed at length during the past twelve months by the Executive Committee and the Council of the League, and a very definite and unanimous decision had been arrived at by those two bodies. He referred more especially to the question of the attitude of the League to coal consumers generally, and especially in the industrial world. They thought after long deliberation that the ideas that the League had before it would be best carried out by regarding consumers of coal as ordinary reasonable beings like themselves, and therefore they thought that they could best achieve the object for which they were working by treating them in a reasonable manner, and by working with them rather than against them. In other words, they thought it was well on every occasion, as far as possible, to capture their goodwill, and they hoped that the members present and all the members of the League would agree that that was a reasonable policy and best calculated to bring success to the League. They recognised, he thought, that owners of power plant, owners of works and other industrial establishments, were not making smoke because they enjoyed it, but that they were making smoke probably in many cases on account of slackness—that was in not taking adequate trouble, secondly on account of ignorance, and thirdly by reason of real difficulties which they could not see their way to solve. As one interested in works at Burnley, he could see the problem from that point of view. He knew the difficulties that they had had for many years with their chimney top, and he knew that there were very many machines lying on the scrap heaps of Burnley which had been paid for by owners of mills and works and which had failed; and therefore the owners of power plant had got sceptical about the apparatus which had

been offered to them and sold to them with the object of overcoming their difficulties. He could, therefore, well enter into the attitude of mind of those owners who seemed backward in spending money on new apparatus which was offered as a solution of their troubles. In 1913 there existed in Manchester a Smoke Abatement League. It was a purely local body which appointed a smoke inspector who was paid out of their own slender funds. He worked for them for about a year ; he had no official standing and no right of entry into works. He made it his job, however, his principal job, to go round to different works in Manchester and district, and talk over difficulties with the firemen and inspect the plant. When he told them that the inspector visited a very large number of works and in no case was refused admission—in every case, indeed, being welcomed, because he entered the works without appearing to have a right to do so and approached the people in a reasonable manner—it was apparent, he thought, that owners of works generally would respond to suggestions if they were reasonable and were placed before them in a proper way. Their difficulty was to know whether the advice offered to them was disinterested. In going round works one found to an extraordinary degree the enormous difference existing in the application of scientific knowledge between the enginehouse and the boilerhouse. One found that the very last ounce of knowledge was put into the equipment of an up-to-date enginehouse, but the boilerhouse was often run very much on rule of thumb lines. A certain amount of legislation would, he supposed, always be necessary, just as it was in the case of factories and workshops, but he sincerely hoped that their League was going to be so active and so useful in its career that in time the various laws which were passed would become almost unnecessary. That might be a far cry, but it was, he thought, the idea at which they should aim.

Mr. A. Lindsay Forster (Messrs. Chance Bros. & Co. Ltd., Glasgow) addressed the meeting and outlined a definite proposal of considerable interest. He did not know, he said, whether enough had been done to emphasise the fact that there was a certain amount of economic attraction in preventing smoke, because the right way to prevent smoke, as a rule, was to carry out combustion efficiently. What were the best lines to follow in getting industry in line and what was the best way to obtain an enlightened state of public opinion ? There was no doubt they would have to face the modification of our legislation. His own ideas of what should be done coincided precisely with the policy of the League—that was that they must look first to voluntary endeavour, to voluntary effort, which after all had always been among the most powerful influences in this country. What were the best steps to be taken with regard to smoke abatement ? They might, he thought, rule out the question of the domestic fire so far as their present discussion was concerned, partly because it was to be dealt with separately and partly because it was less amenable than industrial conditions to corporate action and voluntary effort. The domestic fire was a very difficult problem indeed—first of all because when one began to deal with it, the householder would fear an infringement of his privilege of using the poker. (Laughter). When they came to the admittedly easier subject of industrial smoke they might be presumed to be dealing with what was about fifty per cent of the smoke nuisance in the average industrial district. The suggestion of the

League was that there should be voluntary bodies set up rather in the nature of regional or district bodies. They ought to be voluntary organisations of the industrialists concerned, who would feel that they were furthering the interests of the community in which they lived and made their living, and of the businesses which they represented. They would serve a valuable purpose in that they would collect and collate very important and valuable technical information and their help would be very considerable as they would afford an incentive to the individual manufacturer. If one admitted that further legislation had to be faced—and he did not think that it was a difficult admission to make—once they admitted that they had to consider who was going to frame that legislation. There had been commissions on the smoke nuisance since he was a boy ; they had had reports of leagues and societies of various kinds and he believed he was right in saying that we had an Act of 1875. That Act shows in itself the difficulty of framing legislation which was really intended to deal with what was a technical matter. If they granted that legislation was going to come who was going to promote that legislation ? Who was going to furnish statistics, information and guidance if the manufacturers of this country had not some organisation devoted to the subject by which their views might be put forward quite clearly and in such a way as not to be vitiated by self interest or any suggestion of self interest ? The existence of such a body would be the greatest safeguard we could have against mischievous legislation. It was quite well-known that there were clauses in the Act of 1875 which were really null and void in practice. When legislation came they did not want it to be based on the idea that anybody who emitted smoke was to be an immediate subject for prosecution. What is needed is legislation of an educative character, and he asserted strongly that the greatest safeguard against mischievous legislation was an organisation of the industrial firms in this country who were large fuel users.

Another function which these regional bodies would serve was that they would exercise a pretty reliable check upon people who came forward with freak methods for saving fuel and remedies for smoke. It would not be long before the information at the disposal of such bodies would refute some of the theories that they saw bandied about in the non-technical press by people who were able to get publicity. They would also furnish what he thought was important to-day ; a liason between the industrial users of fuel and the experts, the scientific bodies in this country—such societies as the Institutions of Civil Engineers, Mechanical Engineers, and Electrical Engineers, the Gas Engineers, the Society of Chemical Industry, and other organisations of that kind. One thing he had noticed in the last few years had been a tendency for these societies to become less isolated and to indulge in joint discussions on subjects in which the engineer, the physicist and chemist were equally necessary. Was it not better to look forward to a state of affairs in which the users of fuel, the industrial users, the big companies and the small ones might be represented and might be present themselves at discussion by experts as to the best means of preventing smoke and bringing about an economical state of combustion ? He considered the possibilities in that direction were enormous.

He was not at all sure that one of their most important functions would not be to focus real and steady attention on the best use of what was really our national fuel —coal. They all saw headlines about oil and other fuels, but for ordinary everyday purposes in this country there was only one economical fuel and that was coal. It was on coal that our national industry had been built up, and if it continued, as they hoped it would, it would be on coal that it would work. The more he saw of oil the more he saw that it was not economical except in very special circumstances. Users of fuel and members of such a body as he had visualised would be helped to keep their minds directed upon what was the chief object in view and be prevented from wasting their time and thought upon things which offered no real remedy.

With regard to legislation there was the observance of it as well as the administration of it. Legislation was regarded as a very good reflex of the state of cultivation and social development of a country at any particular time and he had seen it said that the amount of soap that we use was also a good index of our social development. (Laughter). He dared say that legislation was certainly a very safe index. He thought they had before them at the present time an eloquent example of what harm could be done by legislation which was ahead of public opinion. He referred to the drink traffic in the United States. If legislation was passed ahead of public opinion it made public opinion hostile to it. What they wanted was a well educated public opinion and legislation which reflected that public opinion. The Act of 1875 in his opinion, was not deserving of quite so much criticism as had been levelled at it. Anyone reading that Act would find at once that the first intention was to abolish smoke but somebody came along and said that that was impossible so clauses were inserted and compromises effected. The Act represented a very advanced state of public opinion because certain legislators were relatively ignorant on their part before they started as to what could really be achieved in practice. He could not help repeating that the prospect of legislation was one of the things that they should regard as a powerful incentive to set up some body which would save them from such difficulties in the future when new laws had to be made. If they had such a body as the League or Leagues, it would be a great security against any hostility between the administrators of the law and the public who were users of fuel. There were clear evidences that our legislators as well as the public were quite ready for these things and he would like to read to them a statement which might not have reached them there. It was made in Scotland by the Secretary of Scotland and was, "May I say that I trust as the Arts progress that we will have a clearer atmosphere in our great cities. Parliament in its wisdom may do something to get towards that clearer atmosphere, but is it not true to say that if any measure of Parliament is to help in the abatement of smoke it must have the co-operation of the industries of the city. The co-operation of the great businesses of this city is very essential." The Secretary for Scotland was speaking in Glasgow and he clearly indicated that legislation was coming. He said also that co-operation was going to be of the greatest possible value, in fact it was going to be necessary to make legislation effective.

Then there was an instance of a statutory committee set up under an Act in

1892. An Act was passed constituting a committee for regulating the state of pollution of the Mersey and Irwell. The case was sufficiently parallel to that of the difficulties of smoke to make it worth citing. The committee was started under the Act and were given powers, but instead of acting under their powers they regarded themselves rather at first as advisory and consultative. They approached all the people concerned; they asked for their co-operation, and it was hardly necessary for him to say that they had proceeded along these lines up to the present and had achieved a tremendous improvement in the state of the water in the Mersey, Irwell and tributaries. There was another committee set up under similar powers in another part of the country who had achieved hardly anything simply because they regarded themselves as a statutory body with powers and they started to use their powers.

The League would like to see the formation of voluntary organisations of manufacturers and particularly of steam users for the purpose of bringing about the efficient use of fuel with its accompanying freedom from smoke. He imagined that the steam users were included there by special reference because it was a problem that has had wider consideration than had the difficult problems connected with the metallurgical industry. In conclusion, Mr. Lindsay Forster said he hoped he had done something to urge forward the necessity for taking voluntary action and he believed the Smoke Abatement League was going to be the most helpful body around which such organisations could be clustered.

SMOKE ABATEMENT IN BENGAL

B33

by J. ROBSON, Esq., A.M.I.M.E.
Chief Inspector of Smoke Nuisances, Bengal.

(*This paper was taken as read, advance copies having been distributed*).

Endeavours to deal with smoke reduction in Calcutta were initiated under the Calcutta and Howrah Smoke Nuisances Act of 1863, which provided that furnaces should be constructed so as to consume or burn their own smoke, and that the owner must use the best practical means for preventing or counteracting the smoke. That Act, not proving satisfactory, was repealed in 1905. In that year the Bengal Smoke Nuisances Act of 1905, which is controlled by a special representative Smoke Commission was promulgated.

The Act of 1905 and the rules framed under it provide a standard for comparing the densities of smoke, and also provide that smoke of certain densities, if emitted for a longer time than permitted, constitutes an offence. The Ringleman's smoke scales were taken as the means for identifying the smoke, and the denser grades, Nos. 6, 5 and 4, corresponding to dense black, black, and very dark grey smoke, were accepted as the grades to be controlled, and a method was provided for expressing all the smoke of these three grades in terms of scale 6, or dense black smoke.

In 1906, when operations under the present Act were started, some of the chimneys continuously emitted smoke of scale 6, others smoke of scale 5, and some were fairly good. But the average emission of all the chimneys for the three grades of controlled smoke, when reduced in the usual manner, was the equivalent of 13.1 minutes of scale 6 (dense black smoke) during each hour.

The Smoke Act of 1905 was an improvement on the Howrah Act of 1863, as it provided an instrument of greater precision in dealing with offenders. But it only authorised action after the smoke had been manufactured, and permitted the erection of badly designed and wasteful furnaces, from which it was impossible to get a reasonable outturn, or to prevent the emission of smoke, and then punished the owners for making smoke. It missed the basic fact that smoke is, apart from causing damage to the community, an indication of inefficiency, a waste of fuel and a national loss, and that efficient smoke prevention should start at the furnace end of the installation and not at the chimney top.

However, the Commission endeavoured to reduce the smoke as rapidly as possible. The success of its endeavours has been acknowledged in the United Kingdom. In 1914, in the House of Lords, in supporting a Smoke Abatement Bill to consolidate and improve smoke regulations for Great Britian and Ireland, it was stated that " The Bengal Commission had been so successful that in less than three years it had diminished the dense smoke from factory chimneys by over 80 per cent." Though a reduction of smoke had been effected, the Commissioners foresaw that the time was rapidly approaching what a further reduction could not be effected and that the reduction secured would be most difficult to retain, and smoke abatement should be placed on a scientific basis.

A scheme which is entirely voluntary, for the training and examination of firemen for certificates of competency was sanctioned by Government. The firemen are divided into two classes, the ordinary stoker, and the tindal, or leading stoker.

The qualifications for an ordinary stoker are :—

(*a*) He has to pass a satisfactory *viva voce* examination before the inspectors regarding—
- (1) the uses and working of steam boilers and their fittings ;
- (2) the management of the different types of furnaces ;
- (3) the use of various stoking tools ;
- (4) the effect of opening and closing dampers ;
- (5) the effects of too great and too small an air supply ;
- (6) the description of the various arrangements of flues and chimneys ;
- (7) the classification of various kinds of coal and coke used, and their distinctive peculiarities as to steam raising and general heating efficiency ; and
- (8) the prevention of smoke ; and

(*b*) he has to prove by practical test to the satisfaction of the Inspectors his ability to stoke various types of furnaces, and to apply any other test to which he may be subjected.

The qualifications for a tindal stoker are :—

(*a*) he has to pass an advanced *viva voce* examination before the Inspectors in the subjects specified for the examination of an ordinary stoker ;

(*b*) he has to explain to the satisfaction of the Inspectors the working of steam-engines and boiler feed apparatus ; and

(*c*) he has to show by practical test to the satisfaction of the Inspectors his ability to be in charge of a range of furnaces.

The trained firemen effected an improvement, but left untouched the fundamental requirement that efficient furnaces must be provided. Many investigations and tests regarding smoke prevention, coal consumption and draught were made, with the co-operation of the owners, and with a view to arriving at the best proportion of flues and chimneys to suit the local conditions. Proposals were submitted to Government and the Act was amended so as to provide that no furnace, flue or chimney should be constructed, altered or reconstructed unless in accordance with plans previously approved by the Smoke Department. The areas of the flues and chimney are based on the fire grate area, and are as follows :—

		per cent. of the total grate area.
(1)	Back end or down flue	45
(2)	Bottom flue	40
(3)	Side flues	33
(4)	Delivery flue to main	33
(5)	Main flue connected to a grate having an area of less than 150 sq. feet	30
(6)	Main flue connected to a grate having an area of 150 sq. feet or more	25
(7)	Chimney connected to a grate having an area of less than 150 sq. feet	25
(8)	Chimney connected to a grate having an area of 150 sq. feet or more	20

Though the scheme in principle was sound, in practice it gave no appreciable results as about 80 per cent. of the mill owners were unable to submit the required plans. Government sanctioned a scheme under which the owners on payment of a small fee, could have the plans made in the office of the Commission. The results have amply justified the methods.

Having secured the working means for burning the fuel efficiently, smoke abatement and fuel economy became a scientific scheme which rested on :—

(1) Furnace, flues and chimney ;

(2) Boiler, its ability to produce the required steam, and

(3) Steam consumption of the engine, and process work.

Each of these departments should be originally balanced or harmonised and maintained so in operation.

Loco type and Vertical boilers are the worst for making smoke, and some modern Smoke Departments will not have them in the controlled area unless coke is used or they have some approved smoke prevention appliance fitted. This, the Commissioners considered too drastic. On examining the boilers of these classes as made by the makers, some startling results are experienced. In some Loco type boilers the gas area through the tubes is as low as 10 per cent. of the grate, and the area through the chimney is only 9 per cent. of the grate. In some vertical boilers the uptake is only 4 per cent. of the grate, and the chimney is only 7 per cent. Obviously, these chimney areas are inadequate. In and around Calcutta such boilers were fitted with larger chimneys of the prescribed proportion, leaving the areas through the tubes and uptakes alone. These are now practically smokeless and the steam outturn has been greatly increased and the economy in fuel has been improved.

It was early realised that the greatest economy in fuel utilisation would be secured by properly proportioning the quantity of air to the quantity of fuel burned, and this could only be efficiently secured by fitting combustion indicators. But the instruments of those days appeared to be too delicate to survive the every day rough usage of a boiler room. Recently in one of the large mills with 9 hand fired Lancashire boilers, a robust, combustion indicator was fitted, which apparently requires no attention, and is suited for rough boiler use and is believed to be the first of its kind in India. The records show about 12 per cent. of C.O.2. The plant is practically smokeless, with a remarkable increase in fuel economy and marks a great advance in fuel utilization.

The policy of the Commission to ally smoke abatement with economy, and to secure the co-operation of the owners through rendering expert assistance, has been successful, and requests for assistance have been received from all parts of India and other parts of the world. In pursuance of this policy it appeared to the Commission that there was a wide field in Bengal for the use of light fuel which was then a waste product, provided they could overcome the heavy discharge of light grit and ash from the chimneys, which would ruin the adjacent areas for residential purposes. The Commission produced an appliance that overcame this difficulty.

About 1921 for economic reasons the rice mill industry had to use paddy or rice husk instead of coal in the boiler furnaces. The appliance for stopping the discharge of grit from the chimney was fitted and the whole question was anxiously considered, as fuel economy, under local conditions, was of great importance. The results have been remarkable, and has converted a dwindling industry to an expanding one, has effected a remarkable reduction of smoke, and annually saves about a quarter of a million tons of coal in the Province.

When the Act was promulgated ocean-going steamers only were exempted, at certain times, from the provisions of the Act. Subsequent to tests at which Government, the Owners and the Commission were represented, they were brought under the control of the Act at all times.

The Commission are always anxious on the economics and the root cause of smoke production. Their suggestions to the owners, on coal and oil burning, to improve

combustion and reduce smoke, have been incorporated in the old steamers and in the designs for the new. There has only been one prosecution of steamers and that was 18 years ago. Calcutta is an important shipping centre and though situated on one of the most dangerous rivers, is, as regards smoke, one of the cleanest Ports in the world.

The smoke from domestic fireplaces in and around Calcutta is more destructive than that from factories. This smoke, which is discharged at ground level, particularly in the cold evenings and enshrouds localities for several hours in a low lying suffocating smoke pall, has been the subject of anxious consideration by the Commission. The difficulties of dealing with it as a whole appear to be insurmountable. But some relief is being effected by the extending use of gas appliances supplied by the Oriental Gas Co.

In 1906, when the Commission commenced operations, the average emission of controlled smoke from each factory chimney was the equivalent of 13.1 minutes of dense black smoke during each hour. It has now been reduced to 1.19 minutes, or, in other words, 90.8 per cent. of the controlled smoke has been abolished.

SMOKE ABATEMENT IN THE UNITED STATES

By OSBORNE MONNETT, Chicago.

(*This paper did not arrive in time to be printed in advance. It was taken as read*).

The situation with regard to smoke abatement in the United States must in general be described as more or less disappointing. When it is considered that scores of cities have had smoke ordinance on the books for many years, and have made most pitifully small progress, it must be realised that something has been wrong.

Fundamentally, I believe the trouble has been due to an utter ignorance on the part of the public as to the character and magnitude of the work. The idea has been that an ordinance of some kind was all that was necessary to insure final elimination of smoke from the atmosphere ; when as a matter of fact this does not even start the work. Then too, the war period proved to be a great set back for smoke abatement. At the request of the National Council of Defense all smoke ordinances were held in abeyance during this period and it has taken years to get back the ground that was lost as a result of this action.

On the other hand, in particular instances when the subject has been studied thoroughly and a programme worked out to meet the local conditions and adhered to over a period of years, very gratifying results have been accomplished.

From the engineering standpoint, conditions have become fairly well standardised. Theoretically there is a solution for every type of smoker. This holds good more especially with the larger plants. There is room yet for research and development in the field of the small heating plant—the apartment, the residence, the bungalow. The

residence situation is helped in many localities in the United States by the availability of anthracite and pocohontas (low volatite) coal and in some territories by natural gas. In other parts of the country these fuels are not available and such territories suffer tremendously from heating smoke.

There is a tendency to promote the use of manufactured gas for small heating plants, but so far, city requirements as to B.T. and illuminating qualities are such as to prevent the marketing of a cheap fuel gas for this purpose. The use of high temperature coke is making slow progress and there is no true low temperature coke as yet on the market.

Smoke in the average American city can be divided about as follows :—

Manufacturing Plants	45%
Railroads	18%
Residences (houses and apartments)	20%
Large Heating Plants (hotels off buildings) ..	12%
Miscellaneous..	5%
	100%

Based on experience in various campaigns the possibilities of reduction are :—

Manufacturing Plants	95%
Railroads	75%
Residences	60%
Larger Heating Plants	60%
Miscellaneous (metallurgical)	50%

These reduction in smoke density have been made over important areas in various localities. In the city of Memphis, Tennessee, where the writer has just completed a survey, a squad of high school boys without previous experience went out, after receiving instructions and fired all types of household equipment, including open fire places, hot air furnaces, hot water heaters, square and round cast iron steam boilers, cook stoves, etc., etc. Careful records were made on all methods of firing and the average reduction in smoke density for the entire series of readings over a period of two weeks was 60%.

In Salt Lake City, student instructors calling on householders in the morning and giving instruction in firing methods, reduced the smoke 50% in a carefully supervised residence territory.

In railroad operation there is great interest being shown in Deisel engines for switching in conjested territories and in gas washing equipment for cleaning the gases from round-houses.

In general there has been enough work done in this country on the broad subject of smoke abatement, to demonstrate that it *can be done*. It takes longer and costs more

money than was at first realised, but where there is a determined effort to bring about results and a willingness to pay the price, we know it can be accomplished. In most cases also, the expense necessary to better furnace conditions proves a good investment.

During the last year there has been signs of a revived interest in the subject. The initiative general comes from city clubs, and similar civic betterment associations, but not from the manufacturers, who in general still look upon it as an expense and an invasion of their rights. No concerted movement among manufacturers for voluntary improvement of smoke conditions has ever been known here. The idea seems very good and where it can be worked out, should make satisfactory returns on the money and effort expended. For after all smoke abatement and economy are two of the results that go hand in hand with good engineering in the boiler room.

In American cities where real progress has been made the smoke department operates as an engineering bureau, specifying the necessary head room, draft requirements, combustion space, etc., etc., in order to get a satisfactory combination of equipment selected by the owners. No pressure is brought to bear in favour of any particular type, but once the equipment is selected, all effort is made to get it installed under proper conditions.

Advice given to the owner is based on a code of minimum requirements that has been worked out from experience. Cincinnati, Indianapolis, Salt Lake City and Memphis, have the complete code written into the ordinance. This insures permancy. Other cities follow more or less closely these codes but do not incorporate them in the ordance itself.

The best results have been attained by co-operative assistance and not by prosecution. Ten years ago the Mayor of one of our middle western cities told me that he proposed to clean up the town in two weeks. He said that nobody thought of dumping their garbage on the walk at the front door steps, because there was law against it, as a nuisance. Therefore, he proposed to let the people understand that there was a law against dumping great volumes of smoke out in the atmosphere. He mistook the nature of the job. He thought it was a police job pure and simple. Needless to say the city is just as bad off as it was ten years ago.

Briefly, the situation in the United States resolves itself into about the following at the present time.

The technique is well developed and standardised. Successful demonstrations on a large scale have been made. Any city wanting smoke abatement can have it if there is a determination to back sustained high class engineering effort over a period of years.

The difficulty is to find that determination. Heretofore, notable success has been achieved only in places where the smoke was so bad that something *had* to be done. This crystallised public opinion. When enough people want something and want it bad enough, they get it. So I have found it with smoke abatement.

DISCUSSION.

Mr. E. Roberts, Junr. (Chairman of the Manchester and Salford Sanitary Association), said he was one of those who believed there would have to be legislation if the problem were to be solved. In Lancashire, works managers had discussed this question, and while some were ready to take whatever steps were necessary, one manager candidly told him that he found it cheaper to blow the grit out of the chimney than to to collect or utilise it. Consequently, tons of that dust were scattered over the surrounding districts. He also cited the case of a large biscuit firm which laid down a plant in a residential district near Manchester, and fixed five chimneys over ovens which were only a little over 20 feet high and emptied black smoke into the atmosphere. In the first place they ought not to have been allowed to put up their works in such a district. If they did they ought to have been prevented from pouring the smoke into the atmosphere. It was for such cases as that that further legislation was required. He saw a decided advantage in voluntary bodies initiating legislation.

Mr. E. Dickinson, M.I.Mar.E. (Wakefield), spoke in support of the suggestion that there should be formed a body of manufacturers with a view to improving the atmospheric conditions. In 1923 a meeting of manufacturers was called in Wakefield (convened by the Medical Officer of Health), and was largely attended. An Advisory Committee was formed, consisting of technical members of manufacturing firms. This Committee set to work with the view of encouraging industrialists to pay attention to their plant with the object of avoiding smoke. They realised that automatically there would be more efficient working of the plant and more economical results.

A steady improvement had been made as a result of going to the various works and making suggestions. When the manufacturers realised that those visiting the works were also people who were liable to make smoke, and were therefore not interested as officials but simply as improvers of plant, the reception given to the visitors was quite cordial, and they left a trail of friends behind.

The statistics showed a progressive advance in the elimination of smoke. In 1923 the percentage of large chimneys of all industrial concerns that emitted no smoke at all during the period of the observations was 34.6%; the following year it was 44.7% and in 1925 it was 52.2%.

Mr. Hepworth (London) said he had met enquirers of wide experience, and it was astonishing to find the difference of opinion which existed between different engineers as to cause and effect. He suggested the advisability of meetings being arranged at which there could be an expression of views on the part of various engineers who could lay their cards on the table, and tell one another the best way of burning coal economically. He mentioned that his own firm consumed weekly more than 400 tons of coal, and in the ordinary course used Yorkshire washed nuts. In the course of the year they had fitted two kinds of mechanical stokers, and still they were up against the smoke trouble.

Mr. C. V. A. Eley (Birmingham) thought that before framing legislation they should consider the possibility of doing without chimneys.

He alluded to the reference by a previous speaker to the smoke caused by a biscuit firm, and suggested that those five chimneys should have been connected to a conduit, whereby the hydro-carbons could have been burned and the flue-dust trapped before the resultant came into the atmosphere. Then the factory would not have had any complaint levelled against it.

The main reason why the Birmingham atmosphere was so much cleaner than was the case years ago was that many of the smaller boilers had been removed and electrical power had taken their place.

Dr. J. W. Graham (Manchester) pointed out that the new Smoke Abatement Bill was at present before the House of Commons, and under one of the Clauses the whole of the metallurgical industries of the country would be exempted from its operation. He thought that was a great mistake. An amendment should be made removing the wholesale exemption of all metallurgical trades for an indefinite period, and setting up instead an expert committee of the Ministry of Health empowered to exempt individual works, on application, for limited periods as might be found necessary. Their Association would be rendered inoperative unless they could make some improvement in steel manufacture in such places as Sheffield, under expert advice, and keeping in view not only the necessities of manufacturers, but the needs of the public. With new inventions processes improve, and there should be insistence upon the adoption of effective non-smoke producing apparatus, as it was found practicable.

Dr. J. S. Owens (Hon. Sec. Advisory Committee on Atmospheric Pollution) observed that during a comparatively recent visit to steel works in Sheffield he saw furnaces producing high carbon steel, which had to be made in a reducing atmosphere, without the emission of smoke. Although there was plenty of smoke in the furnace, none came out of the stack. The same thing was being done at several works, both gas and coal fired, but there were others from which a great deal of smoke was emitted. The prevention of smoke emission was therefore being effected economically both in coal fired and in gas fired furnaces.

Regarding the formation of an organisation of manufacturers, he strongly held the opinion that the real problem was not strictly or fundamentally a technical one. It was psychological. Did they expect firms to be so altruistic to suggest big modifications to their old works—to bring about reform for the public good and not for their own advantage? That question should be seriously considered. There was plenty of technical information for those who cared to use it. The important point was that the economy in fuel arising from smoke prevention was not large enough to impress manufacturers. It was probable that the smoke coming through the stack did not represent more than one-half per cent. of the whole of the fuel burned, and some manufacturers did not consider that was worth the trouble of saving. In trying to secure reform it was of the first importance that there should be in any organisation that was

formed an adequate leavening of disinterested opinion. If the smoke could be consumed by the manufacturer in the furnace it would be far more satisfactory than sending it out of the stack to be consumed by the general public to their detriment.

Dr. J. T. Dunn (Newcastle-on-Tyne) stated that when recently he passed through Sheffield he saw a dense volume of rich orange smoke being emitted from some steel works. As a spectacle it was fine. As an added constituent of the air it was wholly deplorable. He could not say whether that smoke could be dispensed with ; but certainly an effort should be made to consume it. As regards the importance of the formation of local bodies, there was no organisation which could so completely collect the necessary information for dealing with the problem than one composed of manufacturers. It occurred to him that Mr. Hepworth's suggestion would be largely solved if such bodies were formed locally. He thought therefore that these bodies, if they were public-spirited, would be able more readily than any other to bring the necessary pressure to bear upon any offending manufacturer.

Dr. Cyril Banks (Medical Officer of Health, Halifax) remarked that he had a smoke inspector who was able to go to works and make suggestions, and in many cases where crude inefficiencies had existed his suggestions had led to letters of thanks from firms for the advice given, and some had stated that the new processes adopted had been more economical than the old system. Where refinements of plant were concerned the inspector might, on account of his official position, be unable to suggest any particular make of plant for installation ; he would be limited to taking the manufacturer to see various other works in which different types of apparatus had been installed. The manufacturer then took his choice. That arrangement was not always a success because, as had been stated, many appliances which were boosted for all and every chimney were not satisfactory for every chimney. It was advisable that the manufacturer should be guarded against buying equipment which was obviously unsuitable for his particular boiler plant. Although he did not see how these advisory bodies were to be formed, he thought they would serve a great purpose, and he felt sure that the officials of local authorities would do what they could to assist in the formation of such bodies.

Dr. Munro (Glasgow) stated that they, in that city, were prepared to consider every invention that was brought before the Smoke Prevention Committee, which was known as the Air Purification Committee. Great stress had been laid upon the question of educating public opinion. In Glasgow they educated offending manufacturers by fining them. In the case of the first offence the penalty was one guinea ; for the second it was two guineas ; and for the third offence within twelve months it was five guineas. The Inspectors were well trained and had a sense of duty. In the primary and secondary instruction classes, certificates were awarded to firemen who passed the examination. Many of the big works, including iron, chemical and biscuit works, did not cause any smoke because of improved methods. He was satisfied that the legal remedy was the best.

Dr. Dvorkovitz (London), who remarked that he believed he was the oldest member of that conference, said in 1882, when living at Baku, in Russia, he had to grapple with the smoke evil, which was abnormally bad ; it was so bad that people could scarcely live in the town. The co-operation of the technical men engaged in industry was sought and obtained with a view to finding a remedy ; and he was happy to say that after six months hard work to that end excellent results were obtained. He strongly favoured the formation of local organisations which should be allied to the technical men in the various districts. What was done at Baku could be done in the towns in this country providing that there was the right spirit, and it ought not to be difficult to create that. The fact that smoke meant loss of fuel could not be too strongly emphasised. Obviously, there could not be any standardisation of method to secure smoke elimination, because of the variations in industrial conditions, in the furnaces that were employed, and in the quality and kinds of coal that was used. It was essential, therefore, that local voluntary organisations should have the aid of technical men.

Bailee W. Smith (Glasgow) urged the necessity for bringing pressure to bear upon politicians in order that legislation should be adequate. Efforts were made to bring within the scope of the Bill before the House of Commons a Clause dealing with steamers in estuaries, but it was left out because it was not considered practical. It had been conclusively proved that if there was no undue forcing of steamers, enormous reductions could be effected in the fuel bills, apart altogether from the consideration of atmospheric vitiation. Again, it had been stated that certain kinds of pottery would not glaze except by the use of coal fuel, but members of the League on the occasion of their visit to the Potteries had seen admirable results obtained by the use of gas ; those results included glazing of the highest grade, and economies in fuel and labour costs. It was essential in his opinion that there should be a committee which was more or less independent, and who would be prepared to hear experts upon both sides of the question. It was a fact—a regrettable fact—that the politician had to be educated upon the point that smoke was not necessary. The politician could be moved only by the pressure of public opinion, and branches should be formed, locally, to guide that opinion. Manufacturers could prevent the emission of smoke from their own works if they strove to do so ; and it was true to say that in making that effort no hardship would be occasioned to them, while often they would actually make a profit. He would like to see the condition imposed that in the case of works which produced unnecessary smoke the manager should be compelled to live next door to such works.

Cr. C. Lucas (Birmingham) contended that they should educate in front of public opinion, and also legislate in front of it. As regards the smoke nuisance, it was worth noting that the question of the quality of the fuel used had an important bearing upon it. Atmospheric tests were regularly made in all parts of Birmingham. It was thought that the condition of the air would be improved because of the strike and consequent industrial inactivity, but, as a matter of fact, the position was rather worse than normal, showing that the quality of the coal was a potent factor. Fuel of a poor class had had to be used, and this had created a very large amount of grit. The Corporation Electric

Supply Department had had this experience, and they had found also that fuel of good quality, which was costly, was in reality more economical than a cheap low-grade coal.

Mr. C. Elliott (Hon. Sec. Smoke Abatement League of Great Britain) stated that legislation had not been introduced into the conference as the Executive and Council were dealing with it. He thought it would be useful if they discussed this practical policy because he felt that, in too many cases, the average smoke abatement discussion ran to legislation, like a poppy ran to seed. The policy suggested by the League was a national one, and would have application all over the country. The difficulty they experienced was to get people to think in terms of Great Britain ; there was a tendency for individuals to think too much in terms of their own town. The League knew, of course, that some towns were taking certain steps towards smoke abatement, but the proposition, outlined by Mr. Forster, represented a national policy. It was independent of any one locality.

The policy was quite simple—namely, that there should be established bodies or leagues of manufacturers which could be links between the works and the technical institutions. A local association could get down, so to speak, to brass tacks, and give active and practical assistance which was really required. The Association would have, say, two kinds of inspectors—the one class who would give instruction to stokers, and the other who would be the boiler inspectors. They would inspect all things connected with boilers other than those which concerned possible explosions, because the latter risks were covered by the insurance companies. In many other ways active assistance could be given to the members, and judging by other similar associations the proposition was financially sound.

Mr. Lindsay Forster, replying, said that with regard to the point raised by a member who referred to a biscuit factory chimney emitting black smoke, without having looked at the Act again, he thought he was right in saying that such a factory was not exempt from the Act of 1875, though one of the criticisms levelled at this Act was that it only empowered an authority to proceed against a manufacturer who permitted *black* smoke to be emitted from his chimneys in certain circumstances.

He was pleased to hear from Mr. Dickinson of the improvements that had been effected in Wakefield, and it seemed to him that Wakefield had really anticipated the League's recommendation of regional bodies.

He knew from experience what the difficulties had been in cases in London, and he thought that it would be a great relief to the people of London if they had a local body at their command to give them expert advice of a disinterested nature.

Mr. Graham had emphasised strongly the need for discrimination in the question of legislation. He himself agreed that legislation was necessary, but there was a question of degree as to the extent that legislation should lead public opinion, and he felt sure that Councillor Lucas, whose remarks he welcomed, would not want him to withdraw what he had said. He could bring forward an illustration which would amply justify that view. Where there was a question of legislating ahead there was also a question with regard to the extent to which public opinion was prepared to support it.

The psychology of the question had been mentioned by Dr. Owen, and it was a very important one. In this country we had enjoyed for many years a plentiful supply of the best fuel, but we had been very prodigal in its use. As a nation we had never had the urge of a small supply of fuel, and poor fuel at that, at a high cost, whereas many of our competitors had had to face that. Economy in the use of coal had not been essential in this country as in others, but the time had come when we must live down the tradition of the past in this respect—that we can burn it because it is cheap.

With regard to the suggestion that the regional bodies should be composed of experts only, he did not think that was desirable. They were probably all aware that there were in existence at the present time two bodies for the study of fuel economics specially. One of these bodies laid down a condition that only people with technical qualifications could be members. He thought that such a condition would seriously limit the activities of the proposed regional bodies if applied to them.

As to the best way to form the bodies, it would be granted that there was a close alliance between the corporations of our towns and the citizens who elected them, and he regarded it as likely that corporation action might be the best way to approach the forming of a nucleus in some districts.

Touching on legislation, he thought it was well for them to bear that question in mind. Legislation must be their sheet-anchor, but he hoped it would not come about for the next two or three years. They would meanwhile be enabled to organise a combined effort to bring together the parties affected, and the legislation would only be necessary for dealing with the recalcitrant members.

The Chairman (Councillor Melland, of Manchester), in thanking Mr. Forster on behalf of the meeting for his paper, said that they might take it that on the whole the meeting was in favour of a policy, subject to satisfactory details being worked out of bodies such as had been outlined, being set up. The League could only endeavour to initiate the scheme, and the movement would then have to work out its own salvation.

He would like to assure them that it was far from the intention of the League to lose sight of the value of legislation in their task. They had given the matter a great deal of time and thought in committee and council, and they had come to the conclusion that the time was not opportune to include the subject of the Parliamentary Bill in the subjects for the conference. Meantime, the Executive Committee would go further into the question of the possibilities of setting up the manufacturers' leagues. In one country on the Continent such a body had been a great success for about fifteen years.

ADDRESS

by Sir JOHN ROBERTSON, C.H.G., O.B.E., M.O.H.

AT THE

GRAND HOTEL, BIRMINGHAM,

Tuesday, September 7th, 1926.

The delegates were received by Sir Napier Shaw, Sc.D., F.R.S., President of the League, and Councillor Miss Henrietta Bartlett, Chairman of Birmingham Public Health Committee.

The visitors then gathered for the address by Sir John Robertson, at which Sir Napier Shaw occupied the chair.

Sir Napier Shaw said it was his privilege to ask them to listen to an address by Sir John Robertson. They had been talking all the day, he said, about smoke abatement, always under the impression that every human being desired, if he could, to get rid of the smoke, that he would not be happy until he had. That was the atmosphere in which the Smoke Abatement League lived ; but he did not think it entirely described the situation they had to meet. They might not believe it, but there were persons in the country who believed that smoke was, on the whole, advantageous. He did not know whether the audience believed that—perhaps they did not—but nevertheless there were people who regarded smoking chimneys as a sign of prosperity ; the more smoke the greater the prosperity. They had a certain ground for their attitude, because, unfortunately, up to the present—and until the Smoke Abatement League had achieved its purpose—they might almost say that when there was no smoke there was no prosperity. When there was nothing smoky to burn, smoke was not produced. That was one position, a position which he thought was quite vocal in the North. There was another attitude, which was that smoke was really a good disinfectant, and that we should all perish from infectious disease if it were not for the disinfecting and healthy influence of the hydro-carbons and sulphurous acid that were emitted from coal and smoky fuel. They, of the League, did not accept that position. They believed that smoke was injurious to health. People who took the League's view would on inquiry find it difficult to produce definite evidence—that could not be disputed or passed over by the man-in-the-street—that smoke was directly injurious to health. They wanted definite evidence and statements from people who understood the position that smoke was injurious to health, and that, in so far as smoke could be abated, health would be improved. They had evidence that smoke had been reduced during the past ten years, and correspondingly, the health of the community had been improved ; but there were plenty of people who would say that the improvement in health is one thing and the diminution in smoke another : that there was no connection between the two. In other words, that the public health had improved in spite of the diminution of smoke,

instead of the diminution of smoke being an important contributing factor to improved health. That was a little outpost of difficulty which required clearing away, and he was looking to Sir John Robertson to provide them with means for silencing persons who said that smoke was beneficial to health.

SIR JOHN ROBERTSON'S ADDRESS.

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Sir John Robertson: My first duty must be to say how much I appreciate being asked by the Council of your League to give the address to-night, particularly to so many who are deeply interested in clearing the air, of what is a real and substantial injury to health, and particularly to the health of young children.

There is, I believe, ample evidence of this, and I am hoping to be able to prove this to you to-night.

The general public dislikes dirt and squalor caused by the smoke nuisance, although it does not realise its important effect on health, nor do many of the text books. You will find in these books on smoke abatement that most careful observations are recorded on the bad effect of fogs on mortality. The statement has been made that this increase of mortality, which occurs during the fogs in winter, is mostly due to the smoke in the fog, and you will find stated that ill-health, such as bronchitis, and other pulmonary troubles, is more frequent in foggy weather.

All of this is true, but it is very doubtful as to whether the condition is due to the smoke in the fog, or to the lower temperature and moisture of the fog. Later, I will have to mention another aspect of the smoke nuisance, which, in my judgment, has a much more important bearing on health than that of the smoke-laden fog. I refer to the shutting out of the ultra violet light of the sun by the smoke haze which occurs in all our industrial districts.

There is probably no intelligent citizen who does not want to get rid of the black smoke because of the nuisance it causes in making everything dirty, and in damaging our vegetables and destroying our buildings. Most of these people, however would make a proviso that they would like the smoke nuisance abolished if this could be done without detriment to the industries of the country, and without inconvenience to themselves as householders. If they could see for themselves the children that I see daily, damaged, perhaps permanently, by reason of the absence of ultra violet light, they would take a much greater interest in getting rid of the smoke nuisance.

The time is opportune at present for a consideration of this problem, because, as you know, there is a Bill before the House of Parliament which seems to have a very good chance of being passed. If the Bill is passed, there will be a distinct move forward as compared with the rate at which progress is being made under the legislation now in force.

For practical purposes, the law under which we have worked during the past fifty years has been that sub-section of the Public Health Act, 1875, which makes it an

offence for any chimney (not being a chimney of a private dwelling house) to send forth black smoke in such a quantity as to be a nuisance. The Bill now before the House of Commons deals with this question of black smoke, and also the duration of it. Most of the smaller towns have used this clause continuously to prosecute careless factory owners who send out varying amounts of smoke from their chimneys. Whenever a factory owner has been a litigious person he has contended that the smoke emitted was not black or that it was impossible to do without making some smoke, and he was probably right ; and in the absence of any definite limit in the Act of Parliament he very often succeeded in his contention and avoided conviction. The clause, however, bad as it is, has helped very materially to reduce the total amount of smoke emitted from factory chimneys.

A much more important factor in the reduction of industrial smoke has been the general use of gas engines and electric motors for power purposes, and of gas-heated or electrically-heated furnaces for metallurgical or other purposes. As a result there can be no doubt that the amount of industrial smoke emitted from factory chimneys to-day is vastly less than it was forty or fifty years ago, and however much one may decry the work of local authorities in this connection, the Public Health Act, of 1875, with its local modifications, has drawn attention to the evil, and has been the means of stimulating engineers to devise methods of preventing a considerable amount of smoke. A great deal of credit is due to mechanical engineers for their work in increasing the efficiency of apparatus and reducing the nuisance from the burning of soft coals in boiler fires.

No discussion of the question of smoke nuisance would be of any avail did it not draw attention to the much more objectionable smoke which comes from the ordinary domestic open fire. The less perfect combustion which takes place in an open fire causes the emission from the chimney, not only of soot and acid, but of a very considerable amount of tar. Very considerable progress has been made in the reduction of smoke by bringing into use gas or electrically-heated cooking apparatus and of gas or elecric stoves.

From my point of view as a Health Officer, I should place first, and most importantly the health aspects of the black smoke question ; secondly, I would mention the squalor which is occasioned in industrial areas by the smoke nuisance ; and thirdly, the damage done to vegetation and to dwellings by acid gases.

I have here part of the lung of a town dweller, which is quite black because he has been breathing in particles of carbon all his lifetime. These particles cannot be washed out. They are fixed in the tissue of the lung. On the contrary the lung of a country dweller is pink in colour, and has not a particle of carbon in it. Surely this lung would be very much better without the presence of so much extraneous dirt. Generally speaking, persons who live in an industrial town and breathe sooty air, get their lungs very black. I have seen hundreds of lungs (at post-mortem examinations), and the lungs of the town dwellers were specially black.

It is only within very recent years that the value of ultra violet light in the pre-

vention of disease has become generally known, and the smoky quality of the atmosphere by effectively cutting off this variety of light has done incalculable harm to every industrial community in the past.

The light from the sun, or that from a white cloud, or that from a high power carbon arc lamp may be divided into its constituent parts by being passed through a prism. By doing this we find that part only of the rays which come from these sources is what we know as visible white light, and we find that the visible white light is a blend of all the colours of the rainbow. I have here a diagram of the spectrum of light from the sun. The central coloured portion is the part which we are accustomed to talk of as light. Beyond the violet end of this light portion of the spectrum there are invisible rays, and beyond the red end of the spectrum there are also invisible rays. The public speak about ultra-violet light without understanding what it is and where it comes from. It is sufficient for our purpose to recognise that these ultra-violet rays are invisible and that they are extraordinarily powerful. If one goes far enough beyond the ultra-violet rays one comes to rays which are used in radiography. Similarly, if one goes to the dark invisible rays at the other end of the spectrum one gets the rays or waves, which are used in wireless telephony. The ultra-violet light is then, something that none of us can appreciate with our naked eyes ; and when we come to experiment with those rays that form the so-called ultra-violet light we find they are entirely different from ordinary light.

The ultra-violet rays from a white cloud, or from the sun, or from an electric carbon lamp are very easily screened. For instance, a plate of ordinary window glass, which allows visible light to penetrate screens off ultra-violet light so that a person inside a dwelling house gets very little ultra-violet light. The soot cloud in the air and the tar in the air form a most effective screen for ultra-violet light and prevent it from reaching the surface of the earth. Dwellers in an industrial area when there is plenty of smoke in the air, get very little ultra-violet light.

The cutting off of ultra-violet light produces a series of conditions which are of fundamental importance to the health of a community. One of the effects of living where the ultra-violet light is cut off is that lime salts are not deposited in sufficient quantity in the bones. The consequence is that rickets develops in young children who are kept indoors. Rickets is a disease of the town largely, because the infants are kept indoors or under a smoke cloud. The best and quickest cure that I know of for this condition is to give the patient an abundance of ultra-violet light. I want it to be clearly understood that there are other factors in the production of rickets than the absence of light, but the lack of ultra-violet light is by far the most important in the production of rickets. It is possible to take a litter of puppies and to keep one half of them screened from ultra-violet light and to allow the other half to have abundance of sunlight, and it will be found without fail that in one case rickets develop, while in the other the puppies will be healthy. Again, in certain of the castes in India, it is the custom of the mother to remain indoors with her children, while in the same town other castes do not adopt this custom. The children who are shut up suffer from rickets, while those who

are allowed out in the sunshine do not suffer. When you come to examine the bones of our Birmingham children, as we have been doing now for some time, you will find that a large number of young infants, of a year or eighteen month old, have not got enough lime salt in their bones to make them hard. I will show you come of the photographs we have taken of these children illustrating the effects of the absence of sunlight and of the beneficial results of treatment by ultra-violet rays. Why light should make this difference I cannot say ; but I have not the slightest hesitation in saying that light does it. In Birmingham there is not a large amount of what people would recognise as well-marked rickets, but there is a very considerable amount of early rickets—a type of rickets which can only be recognised by the taking of an X-ray photograph of the bones. These cases of early rickets occur during the winter months when the children are more or less shut up in the dwelling house. A considerable number of these children come from dwelling houses that are back-to-back, where the house faces due north, and where, therefore, no sunshine can get into it. It comes to this, that if a mother can take her young infants into the sunshine for a sufficient number of hours every day the infant will not develop rickets, even in cases where the feeding is not satisfactory.

In some of the towns where flats are common there is much more rickets than in the case of towns where cottages prevail. The difference is probably entirely due to the fact that in the one case the young infants do not get out as much as in the other case.

As I have already indicated, rickets is due to defective deposition of lime salts in the bones of the young and children who have got rickets badly are usually shorter in stature than healthy children. Their general development is below normal ; and, furthermore, taking the average, the child from the slum central districts of the large town or city has not the same height as the child of similar age who has lived in the country.

Rickets may, of course, be temporary and of somewhat minor importance, but the same process of defective calcium deposition is in operation in the case of teeth, and is probably one of the causes of defective teeth among the industrial community. It may be also one of the causes of difficult labour in women, because of defective bone formation, which produces deformed pelvic bones. These become bent by the weight of the body, and labour is in such circumstances attended with some degree of danger.

From a health point of view, therefore, it is very important that young children should have abundance of ultra-violet light from the sun, and this cannot be obtained unless there is a clean atmosphere. Therefore I say that the absence of that light is fundamental.

There is another test which can be applied to demonstrate the soot-haze in the atmosphere of a town. In most of our large cities we frequently get during the summer months a day when we say that the atmosphere is clear and there is not a cloud in the sky. On such a day a photographer could not take in the city a photograph of a rapidly moving object, while an excellent photograph could be obtained five or ten miles away, where there is less soot in the air, that is to say, our sense of sight is not sufficient to demonstrate the soot-haze.

Experiments are being made at the present time to demonstrate the amount of ultra-violet light in various parts of this country, and so far as these experiments have gone they indicate that something like 80 per cent. of the ultra-violet light is cut off by smoke under town conditions. The general public are not yet alive to the enormous importance of ultra-violet light, and, therefore, they do not realise the damage done by soot and tar in the air. All of us are aware of the invigorating power of sunshine when it is dissociated from the heat rays of the sun. It is a common observation that workers in shops and factories become pale and anæmic after the winter's sunless days, while the same workers are restored to vigour when the summer comes round again. Advantage has been taken of the exposure to ultra-light light to increase the vigour of people suffering from exhausting diseases. We are now in Birmingham treating a large number of cases of tuberculosis of the bones by exposing the sufferers either to sunlight or to artificial sunlight, and the results have been extraordinarily good. Everyone knows that workers employed in ill-lighted shops, warehouses, factories, etc., are more susceptible to disease than others. Similarly, babies who are not thriving and who are pallid and flabby, if exposed to ultra-violet light from the sun or to artificial sunlight gain vigour and throw off their wasting condition. I know of no disease that can be cured as easily, if you take it early, as rickets, if you get sunshine or artificial light. St. Vitus' dance and rheumatic affections also responded satisfactorily to the treatment. I have known the jerkiness disappear within a few weeks. (At this point, Sir John Robertson showed a number of photographs of children suffering from tuberculosis and rickets, and of the same children after receiving the benefit of the ultra-violet rays. Their physical improvement was most marked).

There is another aspect of the smoke nuisance which has a very important sociological bearing, that of dirt. Soot dirties everything, with a result that it is almost impossible for a competent housewife in the central districts of a large town to keep her house and her family as clean as she ought to. The labour involved in cleaning is very much greater in town than in the country. The result is that in the town one gets a squalid set of conditions arising from the fact that it is impossible to keep buildings and their contents bright and clean. Those of us who have had the good fortune to visit areas where the soft bituminous coal which we use in this country does not exist, realise what an immense difference there is in the appearance as regards cheerfulness, brightness and cleanliness of these towns, where there is practically no smoke cloud.

There is yet another objection to the general use of coal, viz., the emission of sulphuric acid. The amount of acid discharged as a result of burning coal can be easily calculated, for we know with considerable accuracy the sulphur content of all varieties of coal. I do not think the emission of acid does much damage to human life, because people who live in atmospheres containing much larger quantities of sulphur acids than prevails in a factory town do not appear to be damaged in health by it.

The matter is, however, entirely different when we consider the influence of dilute acid on vegetation, and particularly when this is combined with soot and tar. Sulphuric acid is brought down by rain and moisture ; it is concentrated by evaporation

to a degree which actually burns green leaves at their dependent parts. The damage done to vegetation in our towns is too obvious to need any emphasis. To those who are garden lovers it is one of the most depressing features of town life that they cannot grow the flowers or shrubs they would like to because of the atmosphere. Even in our suburbs where there are no factories, it is impossible to avoid the evil results of acid and tar in the air. It is indeed a pitiable sight to look at some of our open spaces and see the struggles which green things have to continue a precarious existence.

Damage is also done to some kinds of stone used in buildings by the same conditions. Acid in the air, oxygen, rain and sunshine, all play their part, with the result that some kinds of stone will disintegrate far more rapidly in a town than in a rural district removed from town smoke. The composition of the stone itself is of importance. The granites and some of the grit stones appear to resist disintegration altogether, while any stone containing much lime or felspar disintegrates rapidly. Again, all the mortars used in buildings are rapidly damaged, because they contain lime salts in large proportion.

To recapitulate. (1) The greatest damage done by the smoke nuisance is by obscuring the ultra-violet rays from the sun and from white clouds ; (2) the smoke nuisance produces a squalid condition in our industrial towns which has a powerful influence for harm ; (3) there is most obvious damage to vegetation and consequent loss to the amenities which clean healthy vegetation gives ; and (4) there is some damage to buildings.

What can be done to avoid these evils ? I think we must realise that great progress has already been made and is continuing to be made. We do not yet know how to do away with the evil entirely without causing damage to industry and inconvenience to householders.

In regard to industrial smoke, it is now possible for a large boiler installation to be so worked as to produce little or no soot or tar by using a good coal and by having an efficient plant with a mechanical feed. When we come to the smaller boiler plants the difficulty of operating them continuously without the production of some smoke is very great. The smaller the plant the greater the difficulty in ensuring that the stoker will never make a mistake. In the case of these smaller power plants I see no alternative but the use of electricity or gas for power. Many hundreds of such plants have been converted from coal fired boilers to gas engines or electric motors in Birmingham, with very great advantage to the condition of the atmosphere. I do not think it is possible to get a stoker who is going to be infallible in his work and not to create smoke at times.

The manufacturer always complains that the standard as regards the excessive emission of smoke adopted in his area by the local authority is more severe than that in use in adjoining areas, and in a large number of cases he threatens to leave the district. It is very important, therefore, that some uniform standard of control should be adopted for plants of similar size. Many standards are in existence, but I know of none so satisfactory in regard to the amount of smoke emitted as that agreed to by the Sheffield manufacturers twenty-five years ago for their boiler plants. A boiler was not to be

allowed to make more than two minutes of black smoke in an hour ; and there was a graduated scale for numbers of boilers. It was found that that scale, which I believe was the stiffest in the country, was easily worked. Of course, the adoption of any such standard must be a temporary measure, for obviously we must aim at the abolition of all smoke. With a uniform and fairly stiff standard we must be content at the present time. Personally I have no fear but that manufacturers and mechanical engineers will in time overcome the difficulties now existing. The Electricity Bill will go far to assist in this aspect of the problem.

Steam power users have a relatively easy problem compared with many other users of soft coals. Many of the metallurgical processes are more difficult to control as regards the emission of smoke. The forge owners of Leeds or the high carbon steel rollers of Sheffield must have standards of their own. On the other hand there are many other processes in the metal trades which may be better and more economically performed by gas-heated or electrically-heated furnaces. One of the steps which the City of Birmingham Gas Department took many years ago of instituting a commercial gas laboratory where heating experiments could be carried out for manufacturers before they went to the expense of changing their apparatus was a step in the right direction and has been of great value to the city.

As regards domestic smoke much more harm is being done at present by smoke from domestic fires than by industrial smoke. At least this is true of most large towns.

The remedy is the entire abolition of the open fire and the adoption of some scheme of central heating or heating by smokeless fuel very different from that in use at the present time. You are not going to get over this difficulty until you have some satisfactory method of cooking the artisan's dinner, and of warming the house at the same time. The open fire is everywhere recognised as comfortable and thoroughly English. It is a splendid means of ventilating a room. Those of us who have lived in countries where open fires are unknown recognise the fact that the people there keep themselves as comfortable and as healthy without an open fire as we do in England.

Central heating has great advantages over heating by open fires. There is less dust, there is uniformity of heating all over the rooms, which allows one to work comfortably in any corner of a room, and therefore the room is more useful, it is more economical, and I think most people who have had experience of it would adopt a good method of central heating but for the question of the cost. As far as I know there is no method of central heating which can be used for artisan dwellings.

Smokeless coal fires have been much in evidence in recent years. Theoretically, the scheme is a sound one, but up to now it has not been possible to make smokeless coal a practical proposition, and I will leave the question of smokeless fuel as being in the experimental stage, with the hope and belief that some day a process will be found which will enable the smoke-producing part of the coal to be extracted and leave a burnable coke for our open fire places. One old variety of smokeless fuel is of great value. I refer to coke of a quality suitable for ranges and for heating apparatus. In a large number of foreign countries coke is used for cooking and baking, and might be

far more extensively used in England if the gas manufacturer did not extract every particle of hydro-carbon from it.

The cooking range in an ordinary dwelling house is the worst offender in producing smoke. In our towns this source of nuisance is quickly disappearing, for there are few dwellings other than those of the city slums in which the cooking is not done by means of a gas cooker. In Birmingham nearly every artisan dwelling house has a gas cooker ; these cookers probably equal to 80 per cent. of the total number of such houses.

Gas fires, too, play an important part in the reduction of smoke, but much improvement in their construction is yet needed before they can compare with the open fire as a comfortable source of heating. They are, of course, economical and convenient in many situations ; but so far as the poor man is concerned they are, like smokeless fuel, out of the question because they are beyond his means.

If electric radiators could be used for general heating at approximately the same cost or even a little more than that of the open coal fire, there is no doubt that this form of heating a dwelling room would oust all other forms, because of its elasticity in use and its comfort. For the moment, however, electric heating is a luxury for the rich rather than for use by the average artisan. An odd electric fire in a dwelling house need not be seriously considered at the present time as a preventive of black smoke, because the real problem is how to supply the 85 per cent. of dwellings occupied by the artisan classes with a heating apparatus which will warm the house and cook the food. For such an apparatus electricity has not yet become an economical or practical proposition.

There is one point in our present means of domestic heating which is one of great importance from a health point of view, and it is entirely unrecognised by the general public and by architects. It is that the ordinary domestic chimney, whether it be in connection with a coal fire or not, is by far the most important means of ventilating, for instance, a bedroom. No variety of air-brick ventilator or other type of ventilator compares for efficiency as a ventilator with the chimney connected with a fire place. It is, therefore, highly important for those contemplating the erection of any dwelling house which is to be entirely heated by gas fires or electric radiators to see that they provide a shaft which will ventilate the rooms when they are closed in as efficient a manner as the open chimney does.

I do not anticipate any startling revolution in the methods of domestic heating or in the industrial uses of soft coal. Education of the public as to the damage done by the presence of soot, tar, and acid in the air will do more than anything else to produce pressure and progress. I cannot imagine any better means of helping on this educational process than conferences called by Smoke Abatement Societies like the one under whose ægis we are met.

Progress has been great during the last forty years. The air of Birmingham is relatively much cleaner than it used to be, notwithstanding the enormous growth of trade and of population, and this result has been produced by steady pressure on employers

to adopt the best apparatus possible for the elimination of black smoke and very largely to the Gas and Electric Supplies Committees of the Corporation who have aided the work by a supply of heat and power when needed. I am convinced that the more manufacturers know of the newer processes of heating the more likely they will be to adopt them, and the same remarks applies to domestic heating apparatus. We have. however, a long way to go. I am convinced that the really important reason for our compaign is its health aspect. Teach and demonstrate that the smoke nuisance is of real importance to health, and we shall succeed. People are, on the whole, very reasonable if you give them sound reasons for making a change.

DISCUSSION.

Sir Napier Shaw said that there were probably some visitors who would like to ask some questions with which Sir John would deal.

Sir John Robertson, in answer to an enquiry, said the question of the construction of the grate was still a problem. All sorts of grates had been evolved, but after all the most smokeless fire they could get was a coke fire, and he would prefer this in a stove rather than in an open fire in the drawing-room. His hope was that the gas companies would bring out a coke fuel that marked an improvement on the present fuel. So much of the hydro-carbon was taken out that something like a furnace was required to burn it. Large quantities of coke were burned in private houses on the Continent, but stoves, and not open fires, were used almost universally.

Councillor Munro (Glasgow) observed that in that city the corporation had erected a low carbonisation plant at a cost of £30,000, and it was producing daily 100 tons of smokeless fuel. There were customers for the whole of the amount. Experiments were made by one of the Professors in the Technical College, and their chief smoke inspector, and they were able to prove that there was no smoke from the smokeless fuel; and that it had heated a room five degrees higher in temperature, and burned three and a half hours longer than the best coal, the amount in each case being fourteen pounds. Before adopting the plant, which was an experimental plant at Grangemouth, they sent their chemist to make investigations.

The results obtained from the ultra-violet rays in the Welfare Centres had been most successful, particularly in cases of consumption and rickets.

A visitor inquired whether it would be possible for any citizen to take advantage of the ultra-violet rays treatment in the ordinary way as distinct from hospital treatment.

Sir John Robertson replied that this question has not yet been considered by the Health Committee.

Dr. King Brown (London), in moving a vote of thanks to Sir John Robertson, commented upon the informative character of his comprehensive address.

Sir Napier Shaw, in seconding, said he did not think a better illustration of the benefits of fresh air could be cited than that of the Australian cricketers. They had

lived the open life, in an air unpolluted by smoke, and they saw in them a growth that was not stunted. They seemed to be a new race of big men. It was an object lesson as to the immense value of the sunlight.

The resolution was carried.

Sir John Robertson, in his reply, said the Glasgow experiments were being watched with great interest and care ; and he thought it would be found that Birmingham would not be slow in availing itself of any scheme if it were likely to be of any advantage of it. It must be remembered that the conditions were quite different from those in Glasgow. It was more smoky than Birmingham, and perhaps was more in need of an earlier attention.

The meeting then terminated.

Second Session of the Conference

HOUSING *and* SMOKE ABATEMENT

HELD IN THE

CONFERENCE ROOM, BINGLEY HALL,

Wednesday, September 8th, 1926.

Chairman: Sir NAPIER SHAW, F.R.S., President, Smoke Abatement League.

B 4

Sir NAPIER SHAW said that Mr. E. D. Simon, joint author with Miss Marion FitzGerald of the first paper they were to discuss that morning, had for five years been on the Manchester Housing Committee. He was very fully acquainted with the subject discussed in the paper—"Municipal Housing Schemes and Smoke Abatement." Miss FitzGerald had been a member of the Advisory Committee on Housing from 1920 up to the present time.

Miss FITZGERALD, in the absence of Mr. Simon, summarised the paper which follows.

Municipal Housing Schemes and Smoke Abatement

by E. D. SIMON, M.I.C.E., M.I.M.E., *and*
MARION FITZGERALD, Assoc. Roy. San. Inst
Authors of "The Smokeless City."

Yesterday, the conference discussed industrial smoke abatement, to-day we deal with the possibilities of preventing domestic smoke. Opinions differ as to whether the industrial chimney or the house chimney is responsible for the larger share of the smoke which pollutes the air. But there is no need to wait for that disputed point to be cleared up; both kinds of smoke are bad and should be attacked simultaneously as vigorously as possible. The present time, when house building is going on very rapidly, offers a unique opportunity for an attack on domestic smoke by means of improved methods of heating and cooking in the new houses. Unfortunately, so far as the first half million houses are concerned, that opportunity has been largely lost through the lack of enthu-

siasm for smoke abatement on the part of the government department concerned with the health of the people. That the opportunities afforded by the six years which have elapsed since post-war house building began have not been entirely missed is due to the fact that some local authorities have been more progressive than the central authority, as we shall show later.

In June, 1920, the Departmental Committee on Smoke Abatement issued an interim report dealing with domestic smoke only (in advance of their final report), in view of the large house-building schemes then being undertaken by local authorities. The chief recommendation was that "the central housing authority should decline to sanction any housing scheme submitted by a local authority or public utility society unless specific provision is made in the plans for the adoption of smokeless methods for supplying the required heat." The Ministry of Health ignored this recommendation, and they did not commend the suggestions of the committee to the notice of the local authorities until Lord Newton had repeatedly raised the point in Parliament; and the Ministry then reprinted the recommendations in pamphlet form and circulated them with mild comments to the local authorities.

An interesting example of the complete indifference of government departments to the question of domestic smoke is furnished from Congleton, where H.M. Office of Works built, in 1921-22, 138 houses all fitted with Yorkshire ranges—which are admittedly wasteful, smoky and out-of-date—and with coal-fired wash boilers. The local authority has within the last year or two built forty houses itself. In these, the Yorkshire rangeis eliminated in favour of a more economical grate, and gas wash boilers are fixed. The local authority is now engaged in substituting gas wash boilers for the coal-fired ones put in the other houses by the Office of Works.

SMOKE ABATEMENT LEAGUE'S QUESTIONNAIRE.

In order to ascertain whether, in spite of having neither compulsion nor much encouragement from the government, the local authorities had taken any steps towards diminishing smoke from their new houses, the Smoke Abatement League sent out a questionnaire to all urban local authorities in Great Britain with populations of over 10,000. A specimen of the questionnaire and a summary of replies to the questions number A, 1-6 will be found on page 000.

The total number of questionnaires sent out was 575; 362 forms were filled in and returned. Some local authorities had no housing schemes; others did not reply at all.

From the table on page 00 it will be seen that 44% of the local authorities who replied were able to report that the old-fashioned wasteful kitchen range had been eliminated in all their new houses. A further 20.5% reported that they are eliminated in some houses but not in all, while 35.5% have been content to retain this smoky and extravagant apparatus.

Considerable importance attaches to the replies to the question about the provision of gas cookers, because it is generally admitted that the growing popularity of

gas cooking has reduced the smoke nuisance. Where these are fixed when the house is built, the tenants are encouraged to use them. If they have to make an application, and perhaps pay for fixing or hire, or both, they may, and frequently do, decide to do without. It appears that the practice of fixing gas cookers as a matter of course and free of charge is more common in the Scottish towns than elsewhere. Some local authorities stated that there was no gas supply in their area ; others that it was very dear. Others reported experiments with electricity which are dealt with below. Not much use has been made of gas-fires in parlours and bedrooms ; but gas wash-boilers have a majority over coal. Independent coke-fired boilers for domestic hot water supply have hardly been used at all in municipal houses.

What the majority of local authorities have done in the matter of adopting smokeless methods is proba bly as good or better than could have been expected. The chief interest in the replies, however, attaches to the courageous experiments which have been tried by some local authorities (and these not always the largest), chiefly so far as their latest schemes are concerned.

NEW METHODS ADOPTED BY CERTAIN LOCAL AUTHORITIES.

1. Liverpool corporation has put coal ovens in 20% only of the new houses. In the other 80% all cooking must be done by gas, except that boiling can be done on the living room fire, which is provided with a back boiler for hot water supply. The tenants are reported to be "perfectly satisfied." Leeds has one estate (222 houses) on the same principle. It is stated that "no complaints have been received, but at the same time enquiries show that this method is more expensive to the tenants than when they can alternatively cook by means of a coal fire or on gas."

2. The following local authorities report that they have adopted the principal of *one coal fire per house* ; most of them so far as their *latest* schemes are concerned ; Manchester, Edinburgh, Blackburn, Bootle, Barry, Port Glasgow, Renfrew and Dumfries, also Eccles experimentally in 30 houses now being built. In these cases the one coal grate has provision for cooking and hot water supply.

3. A good many authorities have a considerable number of what they call "all electric" houses. Strictly speaking they are semi-electric, because they have one coal fire (with oven and back boiler) in the living room. Liverpool, however, has built 250 *all*-electric houses with no coal fire at all.

Glasgow	has built	(or is building)	766	semi-electric	houses.
Gateshead	"	"	330	"	"
Manchester	"	"	50	"	"
Leeds	"	"	34	"	"
Dundee	"	"	12	"	"
Ilford	"	"	12	"	"
Whitley	"	"	12	"	"

Several local authorities have a few all-electric houses for demonstration purposes.

Some local authorities have put in electric cookers, e.g., Hackney in 114 flats, Lincoln in 50 houses (also electric wash-boilers). In Woolwich, practically all post-war council houses have electric cookers fixed, also plugs in parlour and bedrooms, the tenants finding heaters.

Some local authorities, while fitting coal grates in their houses, have, when putting in electric light, wired their houses for heating also. The additional expense is small if this is done when the house is being built, and, while the authority may not consider that the time has come for equipping the houses with electrical apparatus, the way is left open for the adoption of these methods in future. Among the local authorities adopting this principle are Bermondsey, Preston, Rochdale, Ashton-under-Lyne, Bury, Swansea (in 500 houses), Lytham St. Annes, Peterborough, Ardwick-le-Street, Bentley, with-Arksey, Featherstone and Gellygaer.

It is particularly interesting to note than some quite small U.D.C's have adopted this method. For instance, Featherstone, Yorks, with 15,000 inhabitants, and Gellygaer, Wales, with 45,000, both colliery districts, while retaining the Yorkshire range "because the miners get free coal," have yet wired their houses so that electrical heating can be used in future. It is somewhat surprising that these smaller councils have made provision for modern methods in the future, when some of the larger corporations have apparently given the matter no attention at all.

4. Experiments have also been tried with more extended use of gas. Glasgow has 2,200 semi-gas flats, i.e., one coal fire and all other heating by gas. Leeds has 34 houses on a similar principle, and Whitley has 12. Kensington, Ealing and Chiswick, have installed gas circulators to provide hot water when the coal grate is not in use. A large number of local authorities have carried gas points to parlours and bedrooms although they have not fixed gas fires.

5. A few local authorities have made experiments with central heating. Hull has built 150 and has plans for a total of 1,100 centrally heated houses. A single installation in the living room (slow combustion stove with oven and boiler) cooks, heats radiators in the other rooms and supplies hot water to bath and sink. We have been told that 90 per cent. of the tenants in the houses already finished burn coke, not coal. The Bridlington Council built 12 houses on the same principle experimentally but decided against more. Dundee has 518 flats, heated and supplied with domestic hot water from central stations. Cooking is done by gas and there is a coal fire in the living room. Acton has 20 centrally heated houses ; 12 heated from a central boiler-house and 8 with independent boilers. The tenants appear to have objected to the type of independent boiler chosen ; they found them too large and could not boil pans or kettles on them.

6. Manchester has two large estates of 700 and 600 houses respectively, where hot water to the sinks and baths is supplied from central installations—one of which is in connection with a refuse destructor. The houses should be entirely smokeless in warm weather, but the system is stated not to be completely successful. St. Pancras has 64 flats with a central hot water system.

POINTS FROM REPLIES.

(*a*) Attitude of the local authorities towards the smoke problem.

Some answers showed that the subject of domestic smoke abatement was quite a new one to the authority concerned, and evidently no thought had been given to it by those responsible for planning the houses. They had probably left heating and cooking fixtures entirely to the discretion of the building contractor.

In some instances the officials who signed the replies stated that they were unaware of any smoke problem. From an urban district in the Thames valley "This being a district which is very open, it has not been found necessary to consider the question of smoke abatement." From a Town Clerk in Wales : " There is not much smoke nuisance here ; probably we ourselves are the worst nuisance with our gas-works, but I have heard no one complain."

(*b*) Views of the local authority on new methods adopted as asked for in question B, 2.

This question was not often answered. In some cases where the new methods had only been adopted in the later houses, the time was stated to be too short for an opinion. Hull, for example, cannot pronounce on its central heating experiment. The following comments are interesting. From the Corporation of London :—" From a maintenance point of view, it is found that ceilings and walls of rooms with a small modern type of grate remain clean much longer than those with kitchen range. From a domestic point of view, tenants object to a kitchen range because it is extravagant of coal and because the cleaning of the flues is a 'dirty job.' "

In Barnsley it is regarded as " impossible to eliminate the open kitchen range because it is a colliery district, but a number of electric cookers have been installed in the larger types of municipal houses and are found quite satisfactory by the more intelligent type of tenant." At Cowdenbeath, which is also a colliery district, the kitchen range *is* eliminated and the houses have a modern cooking grate in the kitchen, a gas cooker in the scullery, and gas fires in the bedrooms. The local authority consider they " have gone as far as is reasonably practicable in smokeless methods, bearing in mind that coal is supplied to the miners at a very cheap rate."

(*c*) Opinions of tenants.

These must be received with a certain amount of caution because only an experienced investigator is able to elicit a considered opinion. Allowance must also be made for the conservative attitude which resents a change, even one for the better, merely because it is a change. Mitcham U.D.C. made a canvass and found opinions divided on the abolition of the kitchen range. They conclude that " tenants are guided by what they are accustomed to use." In many cases the opinions expressed by tenants are diametrically opposed to one another. The following samples of replies are interesting :—

Felling U.D.C. reports that miners' wives have *asked* for gas wash-boilers (doubtless on grounds of labour saving), although they get coal very cheaply. In Frimley (Surrey) and Hampton (Middlesex), on the other hand, the tenants who pay full price for coal object to gas wash-boilers as more expensive than coal! The Camberwell Metropolitan Borough Council built 50 per cent. of their houses with kitchen ranges, and 50 per cent. with sitting room grates with boiler but no oven, leaving cooking to be done by gas. The report states that " after experience of four years, tenants seem to be in favour of the latter method. Rooms do not get so dirty." We are told that in Lochgelly, 95 per cent. of the miners' wives prefer small modern cooking grates to the open Yorkshire range in spite of getting their coal at cheap rates. " They find them more economical and to make less smoke." Compare with this Mansfield, another coal mining district, where the local authority has reverted to the Yorkshire range " because the tenants get free coal and therefore no inducement to economy." From Galashiels :—" Gas fires (in bedrooms) and gas wash-boilers are giving great satisfaction to the tenants who consider them to be cleaner and much handier, though perhaps a little dearer than coal ; the extra cost will be made up in general cleanliness." In Renfrew, where the municipal houses have gas fires in all rooms except living room " the tenants' opinions on gas fires are divided." Beckenham (Kent) tenants like gas fires in both parlours and bedrooms, while Irlam (Lancashire) tenants do not like them in parlours. In Mossley (also Lancashire) "gas fires, boilers and cookers much appreciated." In Margate, tenants are said " to prefer coal wash-boilers in which they can burn refuse, gas for cooking and for heating bedrooms." "Artisan" tenants in Lincoln highly appreciate electric cookers. In Barry, where the U.D.C. has provided one coal fire only in each house, the tenants seem to be even more advanced than the council, for in place of the combination grate (i.e. a sitting room grate with oven and back boiler) which is supplied, they would like a sitting room grate with boiler only, because " they prefer to cook with gas." Halifax reports, what is most likely true generally, namely, that tenants " accept innovations " with equanimity.

It is very necessary where any form of apparatus is installed to which tenants have not been accustomed, that explicit instructions as to use should be given.

While it is desirable that tenants should be content with the new methods, and while it is most essential not to involve them in heavy expense for heating and cooking, three important points must be borne in mind :—

(1) the houses will last for 60 or 80 years.

(2) the present occupants are only the first of a series of tenants, and later ones may have more advanced views as public opinion changes.

(3) important developments are rapidly taking place which justify equipping the houses in such a manner that improved methods of heating and cooking may be used, if not immediately, at any rate in the future.

CONCLUSION.

The questionnaire was sent out mainly with a view to ascertaining what the local authorities were doing as regards reducing smoke from their new houses, and it was hoped that by spreading the knowledge of what the more progressive authorities had found practicable, the Smoke Abatement League would stimulate the others to a certain degree of imitation. But more than this has emerged from the replies. The facts set out in this paper indicate that the way *has* been prepared for applying some restrictionss to the domestic chimney. This of course, does not imply that we consider the open fire should be abolished by law, but that the time has come for limiting the consumption of bituminous coal in dwelling-houses. This must necessarily be done gradually, and it would be reasonable to begin with *new* houses. The Smoke Abatement Bill now before Parliament will, when passed, give urban local authorities powers to make bye-laws " requiring the provision in new buildings *other than private dwelling houses* of such arrangements for heating as are calculated to prevent or reduce the emission of smoke." The clause as it stands will enable the local authorities to make regulations for new buildings, such as offices, clubs, hotels, which is all to the good, but there seems no argument at all for not extending the powers, which will be permissive, to new houses. Some local authorities, in whose areas smokeless fuels are dear, and scarce, obviously could not use these powers until conditions change. But it is certain that many years will elapse before a new smoke abatement bill can be introduced, and meanwhile the urban local authorities ought to have this power in their hands to use as and when circumstances are favourable. The bye-laws would probably need to be varied to suit local conditions ; it is not suggested that one uniform type of bye-law would apply over the whole country. The replies to the questionnaire show that certain local authorities have made definite departures in their own houses from the old custom of depending entirely on coal fires and that the tenants accept the change in a philosophic spirit—and in some cases actually with enthusiasm. But those councils, for example, which have adopted the principle of only one coal fire in each municipal house cannot extend that principle to new houses in their areas built by private enterprise. The Liverpool Corporation has found it possible to build 80 per cent. of its own houses without coal-fired ovens, but it has no powers to bring other new houses into line. In Panteg, a small Welsh Urban District, with 10,000 inhabitants, the council claims to have " set a fashion which has been followed in the houses built by private enterprise." Why not give the council powers to make this " fashion " into a rule ?

Now is the time to give the local authorities these powers because house-building on a large scale must go on for many years to come, and the present smoke abatement bill provides the opportunity. All that is needed is to delete the words " other than private dwelling-houses" and to add the words "and cooking" after "heating" in clause 5. The Smoke Abatement League and the Coal Smoke Abatement Society both pressed for this amendment, and it was moved in the House of Lords and the House of Commons, but without success. However, the bill has yet to pass through the

committee stage and it is not too late to press again for this amendment. If the Minister of Health really believes, as he has stated in Parliament and outside, that the greater share of the smoke is due to the house chimney, he should, for consistency's sake, be prepared to accept it.

QUESTIONNAIRE.

SMOKE ABATEMENT LEAGUE OF GREAT BRITAIN.

Housing Schemes and Smoke Abatement Enquiry.

A

Information is specially sought on the following points :—

(1) Whether the ordinary open kitchen range has been eliminated in any or all of the houses.

(2) The type of coal grate used in the living room in place of the kitchen range.

(3) Have independent coke-fired boilers for hot water been used at all ?

(4) *a.* Whether gas cookers are supplied as a general rule and if any charge is made for hire.

b. Have electric cookers been tried in any houses ?

(5) Whether any gas or electric fires are fixed, and if so, in which rooms.

(6) Whether wash boilers are gas or coal fired.

B

(1) Has your authority built any experimental smokeless houses, *e.g.*, all electric, all gas, or centrally heated ? Has any combination of these methods been tried ?

(2) Would you favour us with the opinion of your authority and of the tenants upon any new methods which have been adopted ?

C Can you say what heating and cooking methods are adopted generally in the subsidy houses built by private enterprise in your area ?

D Will you kindly add any further remarks which you consider would be useful to the Smoke Abatement League.

Signature.................................

Local Authority...........................

SUMMARY OF 362 REPLIES TO QUESTIONS A 1-6.

L.A's.	Old Fashioned Open Kitchen Range.			Gas Cookers Fixed.					Gas Fires in Parlours.			Gas Fires in Bedrooms.			Wash Boiler.		
	Eliminated in all houses	Eliminated in some houses	Not eliminated.	All houses		Some houses		None	All houses	Some houses	None	All houses	Some houses	None	Coal	Gas	Some Coal and some Gas
				Free	Not Free	Free	Not Free										
Metro. Boroughs ..	9	8	1	—	9	—	1	8	2	1	14	5	3	9	7	4	5
County Boroughs ..	35	22	19	13	14	—	2	48	9	5	62	15	10	51	5	53	17
Municipal Corp'rat'ns	43	15	42	6	32	2	5	56	1	8	92	4	13	84	28	54	18
Urban Districts ...	49	15	64	8	42	—	2	75	10	8	110	12	12	104	46	57	24
Scottish Burghs. ..	23	14	2	24	9	3	—	3	4	2	33	7	12	20	5	27	7
	159	74	128	51	106	5	10	190	26	24	311	43	50	268	91	195	71

Some L A.'s did not answer every question.

B4

Mr. POINTON TAYLOR, in the absence of Dr. Unwin, then read the following paper :—

CLEAN AIR AND CLEAN HOUSES

By RAYMOND UNWIN F.R.I.B.A. (Chief Architect, Ministry of Health), and POINTON TAYLOR, F.R.I.B.A. (Chief Assist. Architect, Ministry of Health).

The recuperative power of clean air is recognised as instinctively as is the necessity for breathing in the presence of any mixture of gases with which for a time we may be surrounded. The gas masks and helmets used to neutralise the fearful concoctions hurled by civilised nations at their civilised foes, are perhaps the most outstanding recent reminders that if we must live we must obey those natural laws in accordance with which we have been evolved. Nature might, in course of time, evolve human organs to suit other conditions ; but science seems to have travelled in some directions a little faster than nature, and the process is so insidious that much damage is sometimes done before the cause is fully appreciated.

In the particular circumstances which we are considering, namely, the superabundance of smoke which at present is part of our daily fare, we of this generation have been slow to recognise the evil, and slower to prevent it. Rather have we flown to cures. The rich amongst us have sought the clean air districts, zoning being instinctive when circumstances favour it. The well-off families, if tied to town, have adopted the week-end and holiday habits, spending such times in the less polluted air of the country villages or seaside towns. Nearly all the remainder who can live in the inner or outer suburbs with such mitigation of air pollution as circumstances permit. All the way down the social scale the desire to breathe pure air persists.

Many of us travel up to town daily by railways frequently used by thousands of children who are brought for one day each year to the nearest buttercup fields or bluebell woods, shouting happily as they debouch from packed carriages in the morning. Often we meet them coming back to the station in the evening mostly staggering under an armful—nay, two arms full of field and hedgeside flowers. Invariably we are informed they are "for mother," and nearly as invariably they are used for pillows for weary heads ere mother is reached. Perhaps these are the all-important little people whom we must help towards a better mode of life in cleaner houses and environment.

The latter under the present conditions of commerce can be best achieved by that factor of town planning known as "Zoning," or the proper use of land in any given known set of circumstances. Where town planning schemes are made by the local authorities, they can allocate certain convenient areas for industrial purposes, and can select areas where any smoke that must be created will do the minimum of injury. They may also exclude factories or other smoke creating industrial buildings from residential areas, and thus do much to protect people from the evil of industrial smoke and dirt.

The theory of zoning is just as simple as this, and given a new town its practical application is similarly simple. The factories in such a town would be located as at Letchworth, so that not only are these reminders of daily routine hidden from the homes in which are spent the hours of leisure, but the prevailing winds diffuse such smoke as it necessary from their chimneys in directions away from the town's living quarters. Public services are directed through convenient channels with the minimum waste of time and energy, and the economies effected by such means go a long way towards providing the amenities which are the normal perquisite of proper living. In the ordinary way these amenities in our existing haphazardly developed towns are often only obtained by heavy burdens on an already overtaxed population, which considerably diminishes the natural enthusiasm for civic adjuncts, be they in the form of dignified buildings set in generous "places," encouragement of the arts and sciences, or the provision of ample parks and recreation grounds. The will to provide these things is there, but the power is limited, and it is only by the application of common sense town planning practices that clean and beautiful towns can eventuate. Under the possible conditions of town life, where every legitimate desire is catered for, few would prefer to be farther away from its attractions than the population density rendered essential, while those nearest the centres of activities would be envied.

In a town already built, the aim is the same, but the procedure must needs be more difficult and slow, though the principle of zoning can be applied to the areas round the town over which it is about to spread. Our insular dislike of radical change, whilst appreciating the desirability of it, added to the technical and financial difficulties, will not allow quite practical visions to mature as quickly as the eager enthusiast will desire and it will be long before many towns will free themselves from the accumulation of undesirable factors due to the want of reasonable forethought or change of conditions.

In the meantime, however, whilst the municipalities are preparing their plans for the ultimate rescue of their areas from the industrial smoke nuisance by adequate zoning, there are numerous improvements which can be tackled immediately, not the least of which are concerned with the abatement of smoke from buildings of all kinds.

One aspect of this question, and by no means a small one, relates to the amount of smoke, if any, which the small dwelling need be responsible for producing. It is an aspect to which very careful consideration has been given by the Ministry of Health in the administration of the various Acts dealing with assisted housing during recent years. Whilst the varying circumstances have not enabled any statutory requirements to be formulated, many proposals by local authorities for heating, cooking, and hot water installations, wholly or partially eliminating the use of raw coal in houses, have been systematically encouraged, and others have been sympathetically considered for experimental purposes. Certain methods resulting in the reduction of smoke formed the subject of more public advocacy through the columns of a periodical called "Housing," an official publication of the Ministry of Health during Dr. Addison's term of office.

In the issue for August 2nd, 1920, an article, entitled, "Smokeless Heating for Cottages," began :—

> "The necessity for abolishing the smoke nuisance, air pollution, and the waste involved in consuming raw coal is now admitted on all sides, and our present concern must be to devise methods of keeping warm without contributing to these unwelcome conditions. . . . We should look principally to gas and coke as sources of heat. Electricity, unrivalled as an illuminant, is not as a rule economical for heating owing to the waste involved in first converting fuel into mechanical energy."

Since this statement was printed much progress has been made in some places regarding the use of electricity for other purposes than lighting, and it is undoubtedly an alternative to be considered.

As practical evidence of the support given by the Ministry to such proposals, several houses were erected in 1920 at Acton Wells, demonstrating various methods available eliminating the use of raw coal.

It will be realised that the application of improved methods depends very largely on the circumstances and conditions under which small dwellings are to be erected, and that the actual cost in hard cash to the tenant looms very important to them, even though the housewife may appreciate very greatly other advantages which are not so easily reckoned in this all-important medium of exchange. In country districts, for instance, there are many places where the absence of a supply of gas or electricity renders coal supplemented by wood or peat the only heat-producing materials available. Again, assuming such facilities were available, a proposal to instal smokeless methods of heating and cooking, even at reasonable cost, in a Yorkshire mining village, where a ton of poor quality coal per week is supplied to every household either free or at a very low rate, would receive little encouragement from the tenants of the houses. Under such conditions the fires only " go out " by accident or when repairs to the grates are necessary. This rather archaic perquisite serves as an example of waste of raw material, which should, and no doubt will, be put to better use in the early future. In this connection there is the possibility that the low temperature carbonisation process will provide suitable smokeless coke for burning in open grates on a commercial scale, and offer another alternative method for heating and hot water supply, which is likely to be more popular than some of the alternatives now available. In fact, the scientific progress which is being made at present towards the provision of smokeless fuels makes the position by no means easy to dogmatise upon.

The present position of the small dwelling in reference to the smoke problem may perhaps be stated as follows :—

(1). As regards cooking in houses built since the war.

(*a*) Coal gas has been widely and generally adopted for cooking purposes, and apart from cost may be looked upon as the most popular of the non-smoke producing methods, except in places where the price of gas is high although

the price of coal is low. Such cases are exceptional, however, and generally the greater efficiency and economy in use of coal gas balances its higher cost per thermal unit.

(*b*) Electricity is also so economical in use for cooking with the most efficient apparatus that this goes far to balance its still higher cost per thermal unit ; and where suppliers and local authorities are laying themselves out to supply it cheaply, say below 1d. per unit, its use in small dwellings is growing, and may be regarded as a practical, and from a smoke abatement point of view, an ideal alternative to raw coal.

(*c*) Coke or anthracite can be used for cooking in suitable ranges, and both are economical where supplies are available. An increase in the supply of the former is likely in view of the urgent commercial necessity for making better use of all the by-products obtainable by converting the raw coal.

Ranges to be suitable for the use of such fuel must be made so that the supply of air is under proper control. The absence of flame to heat the oven requires that a high temperature for the flue gases shall be maintained. This result can only be attained if the inrush of cold air can be restricted to the volume required for combustion.

Further research into the best form of grates for burning coke appears desirable, and an increase in the demand for such grates would be one of the most effective means of stimulating both experiment and adequate supply. The methods by which such a demand could be created are of considerable interest. It has been suggested, for instance, that local authorities, where conditions are favourable to alternative methods, should be empowered to make bye-laws requiring that only such type of coal burning grates should be installed in new houses for cooking or heating as would be suitable also for burning coke or other smokeless fuels.

(2). As regards water heating.

(*a*) Coal gas is used in many houses to provide bath and general hot water by means of circulators, geysers, various kinds of water heaters and washing coppers. There are also small boilers attached to some cookers in which the water is more or less heated by the waste heat from the gas used for cooking as may be unavoidable. The partially heated water is brought up to the required temperature by a small gas ring without entailing great expense.

In some districts where these methods have been tried they have been regarded as costly, and the older methods have been reintroduced, but such cases are comparatively rare.

(*b*) Electricity appears to be in its infancy as regards its utilisation at reasonable cost for general water heating purposes. Nevertheless, in some places where there are periods of small load, and where current can be supplied

during those periods at low cost and the heat stored up in the hot water tank, the use of electricity for heating the water for cottages is proving a practical proposition, and a number of "all electric" houses have been adopted. There are also appliances for the purpose in which the current is automatically regulated by the temperature of the water, the tank being connected to the required supply points in the usual manner. We do not know of these appliances being used extensively in working-class houses, but rather in places where a little extra cost does not outweigh increased convenience. It is an ideal method, and one to be watched with interest and hope.

Electrically heated kettles and irons have been supplied to tenants of small dwellings ; at least one case is known where tenants re-housed from cleared slum quarters are using these appliances in conjunction with electrical cookers, and express great satisfaction at a reduced expenditure compared with their old conditions. The cost of the current per unit in this case is one penny.

(*c*) There is not much doubt that, where obtainable at reasonable prices, coke is at present the most economical fuel for water heating, where anything like a constant and fairly sufficient supply is needed. A high pressure back boiler to a kitchen range under these conditions *seems* economical, but it frequently tends to diminish the efficiency of the range for cooking, and by cooling the combustion chamber also tends to increase the smoke when soft coal is used.

Probably the best method for heating a constant supply of hot water is to provide it by means of a small simple stove specially designed to burn coke or combustible rubbish. The opportunity of doing the latter piece of scavenging work is a great attraction to most householders, for besides saving much public scavenging, the obtaining of local value out of otherwise useless rubbish leaves a satisfactory feeling of duty done behind it. This small boiler would be connected to a circulating system on the usual cylinder system, and the hot fuel gases after they have passed the boiler may be arranged to heat a small oven.

The next best method, perhaps, is to provide a back boiler of fair size, but separated from the fire by a slab of firebrick, and so arranged as to absorb chiefly waste or surplus heat A small gas or electrical heater could be used if need be to heat up to the required temperature the warmed water, or completely heat it in the summer when the coke fire is not in use.

The use of coke in the range or in the fire used for heating presents no difficulty as regards its water heating function.

(*d*) A word must be said about communal continuous hot water supply, which has been successfully adopted in connection with tenement buildings, and less frequently in connection with isolated cottages.

With regard to such supplies some trouble and expense arises from the wasteful use of easily obtained hot water ; this is perhaps partly due to the sudden change from a difficult to any easy supply. The use of a simple meter, when available, would overcome the difficulty.

In many cases there appear to be no complaints, and, carefully used, the provision is a good one, and the cost to the normal family compares reasonably with other methods. One shilling to eighteenpence per week is a common rent for this service.

(3). As regards smokeless continuous heating for rooms.

(*a*) Both coal gas and electricity are at present too costly for this purpose for working-class houses.

(*b*) There are ordinary coal burning grates which do a little to reduce the smoke, and their use with careful stoking may effect some abatement. Where, however, they are stoked carelessly, it is doubtful if any of them do more than reduce the smoke evil by a rather small and indefinite amount.

(*c*) Coke and anthracite can both be used in open or partly open fires, if these are designed for the purpose. A number of patterns are already on the market. The low temperature carbonised fuel will burn also in such grates.

Dr. Fishenden considers that most open fires will effectively burn high grade gas coke which has a low ash, and a low moisture content and increased demand would soon produce a supply of economical grates adapted to coke burning.

The coke boiler which was mentioned in connection with the continuous hot water supply could be arranged to heat one or more radiators which would give permanent warmth, and could be supplemented by a gas fire or electric heater for occasional use.

(4). Intermittent heating.

This usually applies to the parlours and bedrooms of working-class houses, and from a smoke producing point of view is a comparatively negligible matter, even though ordinary coal burning grates were installed, as their use is so slight.

Nevertheless, for such purposes the rapid full heat of a gas fire or electric heater is so convenient that where such services are not prohibitive in cost, householders could well utilise one or other. A plug for the attachment of an electric radiator or a connection for a gas fire which can stand in front of the ordinary grate is a small matter as regards capital cost. For occasional whole day uses of any particular room, or for long illnesses, the coal or preferably coke fire would be available, as the cost of continuous use of gas or electricity might be prohibitive for cottage tenants.

It is not easy to set out a general non-smoke producing scheme for heating, cooking and hot water installation for a working man's house. Much depends, as will be clear, on the particular conditions of the district, the availability and comparative capital and running costs of the various alternative services, and on the class of family which has to be catered for. Mr. Barker, in his enlightening experiments, has fully demonstrated the need for considering the latter point if scientific efficiency is to be aimed at ; although until every man builds or equips his own house it is difficult to see how all possible circumstances can be provided for without overloading capital costs. More might, however, be done to provide the means of suitable alternative equipments. A few extra gas points or electric plugs are not very prohibitive as regards cost, and would meet many cases.

The provision of suitable extract flues for the products of combustion of coal fires is a matter fully dealt with under the building bye-laws of local authorities. In addition to this purpose, such flues act effectively as extract flues for ventilation purposes.

Ventilation for rooms without fireplaces is also dealt with in most codes of bye-laws. The usual requirements in this respect do not, however, provide for the modern gas fire. In the interests of health it may well be that to require more adequate means of extracting the products of combustion from rooms in which gas burning apparatus are used than are at present compulsory, has become desirable. The use of gas in some cases has been discredited for want of such provision. Whether compulsory or not, an extract flue of adequate area, so arranged as to minimise the danger from down draught, should be provided to every gas fire ; and where this flue provides only for the products of combustion, a second extract flue for ventilation rather than a mere air grate through the outer wall, would probably give more effective circulation of air. At least, it behoves us to recognise that the value of the smoke flue for ventilation is one of the reasons why people cling to the coal fire ; and the question of securing equally good ventilation when gas or electric heating is adopted, forms a necessary element in successful propaganda for smoke abatement.

We have recently been informed by eminent scientists that the effect of climate upon man's mental and physical welfare is probably more important than any other single factor. Most of us had probably appreciated the varying effects on our health and spirits of periods of sunshine or clouds, but to have it stated as being of such paramount importance will increase our ardour in the fight against the grimy despoiling agent of our wonderful natural climate, who has long outstayed his original welcome.

RAYMOND UNWIN.

S. POINTON TAYLOR.

Mr. Pointon Taylor, after reading the paper on "Clean Air and Clean Houses," said he would like to refer to the paper read by Miss FitzGerald, in which it was stated that the Ministry ignored the recommendations of the Departmental Committee on Smoke Abatement issued in 1920, and supplied to the Ministry ; and that the Ministry had failed to commend the suggestions in the report to local authorities. This statement was hardly correct. In December, 1920, a memorandum was issued by the Ministry to all local authorities which, he contended, embodied the Committee's recommendations. Outlining the memorandum, he suggested that its recommendations could hardly have been couched in stronger terms. Apart from that they had to remember other points in connection with State-aided housing in this country which had bearings on the smoke problem. The principle had been accepted that it was sounder to build houses at 12 to the acre rather than at 30, 40 or 50 to the acre as had been done in the past, hus diffusing such smoke as might be necessary. Further, great importance was attached to the proper aspect of rooms, so that as much sunlight as possible could be got into them, thus reducing the effects of the smoke evil. These schemes, obtained in every city, borough and parish in the country, and had in the earlier stages been carried out under very trying conditions. He thought it was rather a waste of time to point to a few failures in view of the mass of precedent for good work. He was perfectly prepared to say that more might have been done, but with regard to local authorities' schemes freedom of action was a matter that the Ministry of Health had to consider very carefully. They could point out the way and indicate that in their opinion this course was a good one and that was not so good, but within reasonable limits freedom of action was a very important part of our British constitution.

Bailie Smith (Glasgow) said they could do much towards smoke abatement in the new houses they were building all over the country, but after all, in proportion to the whole population the number of people in new houses was really very small—one, two or three per cent. They could not, as health authorities, afford to wait until the whole population was housed in new houses before they cleansed the atmosphere. It was the duty of professional men, including the doctors, to point out and preach against the evils of the smoke-laden atmosphere. Sir John Robertson gave them a strong lead in that direction. It was for all of them who were members of local authorities to get measures for counteracting the evils of smoke adopted in their areas. In their case the role of Pied Piper had been taken by those whose inventive genius had been employed to rid the community of their plagues, and they must follow. There were those millions of small houses of which neither the landlord nor the occupants could afford the capital expenditure necessary to change over to electric and smokeless heating systems for a long time to come. His own opinion on that point was that they must give the people a smokeless fuel they could burn easily in the grates they had in the old houses. It was stated in the report on the coal industries that the burning of raw coal not only prevented the recovery of the derivatives, but led to the pollution of the atmosphere and made against the public interests.

The atmospheres of our towns, even in the industrial districts, could be made

smokeless. This nation could obtain from her own soil, by the treatment in operation in Glasgow, a great amount of oil for purposes for which natural oils were mostly imported. This would render the country to a large extent independent of the imported oils, and would yield a supply sufficient, he thought, for the Navy, Army and Air Force. There was nothing now to prevent any local authority, owning its own gas works, from extracting that oil to-day. He urged them and the big industrial companies to have plants installed by which they could get this valuable by-product, and in addition turn out the smokeless fuel referred to by Councillor Munro, as they were doing in Glasgow, and sell it to the people. It would burn satisfactorily in the oldest grates. The thing was an assured commercial success, and it could be sold at the price of a good household coal.

Mr. Roberts (Manchester) said he agreed with Mr. Bailie Smith that smokeless fuel was no doubt the best for oven fires. It was much better than the ordinary gas coke. He invited reports on the merits of gas coke from his tenants whom he had requested to use it, and he found their principal objection was to the fact that when the coke got heated it crackled and flew out into the room. Many of the modern grates would not burn coke. He would not now have any grate installed in a house of his that had any bars in it. For most rooms there was nothing like the barless grate with the sloping back.

The question was, what were we doing to get the tenants of the older types of houses to use smokeless fuel and to get gas and electricity installed? He got over twenty of his tenants to agree to having electricity in their houses. Did Miss FitzGerald state that it cost no more to instal power, for he found that it cost quite 50 per cent. more to put in power than lighting. The majority of the tenants, having seen the results which the others obtained (with the Norwich system), had since requested him to instal the power in their houses. The pioneers in this experiment were well satisfied with the results. He thought that now it would cost little more than the instalment of gas-heating, and there was no doubt in his mind that electricity was preferable to gas, both for heating and lighting. All the gas fires were taken out of these houses.

He was glad to hear Mr. Pointon Taylor emphasise the necessity of flues where there were gas stoves. So many people erroneously thought that they could do away with chimneys. That was a great mistake. Many of them would no doubt remember the case in Manchester in which the poisonous carbon monoxide from the gas got into a room with fatal consequences. There was really need for a better chimney with the gas fires than with the old coal fires. If there was a deficient flue where a gas stove was in use it was not so easily observed, as in the case he had referred to where a friend of his was killed by carbon monoxide escaping into the room, unknown to the occupant. Housing authorities would be well advised to bear this in mind, and see that good flues were provided where gas stoves were installed.

Dr. Fishenden said that it was not to be expected that the householder should risk the capital expenditure involved in any very considerable alterations of his heating or cooking appliances, but that the aid of those responsible for the equipment of new

houses would have to be invoked. As Mr. Simon and Miss FitzGerald had pointed out in their paper, the present time, when building was going on so rapidly, was an opportune one for vigorous action ; otherwise, faults which might have been remedied would probably be repeated in new houses. It was consequently of great importance that architects, builders, grate manufacturers and all authorities concerned, should be cognisant of the best methods of fulfilling any given requirements, and should be kept informed of such advances as might from time to time take place.

Dr. Unwin's warning, however, that the average housewife, although appreciating other advantages, would judge alternative methods largely by their running costs, must not be disregarded ; and the building of houses which, although smokeless, involved the householder in increased fuel or energy costs, would tend rather to confirm prejudice against innovations than to help smoke abatement forward. The best way of avoiding such an undesirable result was, as already suggested, the proper education of those concerned. Reforms should follow advances in knowledge, but in practice there was usually a considerable lag, due partly to ignorance and prejudice, but partly also to the cost of scrapping old equipment and inaugurating new methods. It was one of the functions of the Smoke Abatement League to combat ignorance and prejudice, and to help to ensure that in the construction of new houses every advantage should be taken of available information.

There were many different methods of generating heat. It might be produced by the combustion of either solid, liquid or gaseous fuels, or from electric energy. There were again numerous different types of appliances available for use with any given fuel. Faced with so many alternatives, the choice of equipment was not always altogether apparent to the specialist. To the ordinary householder, who as a rule was not in a position to obtain disinterested advice, it was bewildering. The nature of the installation likely to prove most satisfactory in any given case would depend closely upon the demands, but would generally necessitate the use of more than one form of energy.

In general, heat was required in our homes both for warming rooms, cooking food and providing hot water. But the relative importance of these different services varied widely according to circumstances. There were numerous offices, for instance, where no cooking was done and where the warming of rooms was the primary requirement. In restaurants, on the other hand, heat was required mainly for cooking purposes. Even purely domestic requirements varied considerably according to the standard of living or the habits of a household ; some families using far more hot water than others, some having relatively heavy cooking requirements. And since some functions were best carried out by one form of energy or type of apparatus, some by another, it was not possible to formulate any single scheme for the equipment of houses which would be equally suitable or economical in all cases. For the same reason it was, in her mind, no more reasonable to insist upon "all-gas" or "all-electric" equipment than it would be to advocate "all-wood" or "all-glass" houses.

As Mr. Simon and Miss FitzGerald had pointed out, many of the so-called all-

gas or all-electric houses retained one coal fire with provision for cooking and hot water supply ; but since a large part of the coal which was used in small houses found its way to the kitchen range, it was not to be assumed, unless the type of range installed produced less smoke than the old-fashioned kitchener, that such equipment contributed very greatly to smoke reduction, although the housewife might find it more convenient.

The amount of raw coal per head used for domestic purposes showed no signs of decreasing in spite of the growth of the gas industry. This fact suggested that the demand for a solid fuel was likely to continue, and there was an urgent need for putting on the market a satisfactory smokeless solid fuel to replace raw coal. Gas coke as ordinarily supplied had many drawbacks for domestic use, but there was no doubt that a satisfactory solid fuel could be produced. It was all a question of economics. In the low temperature process the yield of gas was reduced, and in consequence, if the solid product was to be sold at the same price as gas coke, either the other by-products would have to fetch increased prices, or the running costs of the installation would have to be reduced below those associated with existing gasworks practice. Gas cokes also might be improved by limitation of ash and moisture content and by proper grading. The department with which she was associated had recently carried out some interesting attempts at producing a more free-burning coke from ordinary vertical retorts by increasing the rate of throughput, and had obtained very hopeful results. There was little doubt that the future would see an increasing use of some form of coke.

Dr. Cyril Banks (Halifax) said that there were large numbers of tenants who would be only too glad to turn their houses into smokeless ones, but if they were occupying their houses on a precarious tenancy they could not afford to do it, and in many cases, if they approached their landlords about the matter, nothing resulted but a rude answer. They should watch with interest the extension at present taking place in the activities of the large building societies which provided a way by which people could become the owners of their own houses on reasonable terms. These societies should command the attention and interest of all who were engaged in the cause of smoke abatement. Owner-occupiers would be more likely to adopt smokeless methods than would persons who rented their homes.

Dr. Owens (London) said that, physiologically, the smoke problem was more important to the working man than to anyone else. Some few years ago he embarked on experiments to ascertain the amount of smoke we breathed, and soon found that the nose, as a breathing apparatus, did not remove the smoke Seventy per cent. of the dust and smoke we breathed passed through the lungs and out again, leaving about 30 per cent. behind. If we breathed quietly, the air in the depths of the lungs was nearly dust free ; but not during deep breathing. He wanted to ask them what class of people in this country did the most deep breathing. They would at once perceive that it was the working man, and he, unfortunate fellow, had to work in the most dusty places. Therefore it seemed to him that the working man was the one who should be most interested in smoke abatement.

He was going to venture on a little criticism as to the application of common

sense to the problem of zoning. He was going to apply commensense to the principles of "zoning," and reach a conclusion the reverse of that arrived at in the latter of the two papers : It was stated that the principle involved was very simple, that is if they put the factories outside the town, commonsense would tell them to place them in such a position that the prevailing winds would send the smoke away from the town. That was the inference drawn in the paper, but commonsense told him to put them on the other side so that the winds would blow the smoke across the town. The reason for that conclusion was that when a chimney emitted smoke into the air the only thing to clear it was the wind. The velocity of the wind was an important factor, and curiously enough there was an immense relationship between the velocity and the smoke density. The high velocity wind is the scavenger, and when the smoke has been carried away by that it became so thinned and diluted that it did not much matter where it went. They never got a London smoke fog when there was a high wind blowing. Fogs invariably came with a low wind—perhaps only two miles an hour—and always a wind in the opposite direction to the prevailing wind which, in the case of London, was south-west. It was the anticyclonic or more or less easterly wind that slowly drifted the smoke along, and sometimes held it down in a thin concentrated layer all over the countryside. Such were the conditions which concentrated the smoke—the low velocity wind which drifted it along in a dense layer. Therefore, commonsense told him that you should put your factories on the side of the town which the prevailing winds struck.

There was another point he wished to make. He would be very sorry to see the all-electric house. The average Englishman did not like his windows open nor any other openings for that matter. He looked to the chimney for ventilation. Put him in an all-electric house and he would be dead in a few years. He thought an all-electric house would be a calamity. He agreed that what was wanted was a reasonably clean, cheap, solid smokeless fuel. For many years the attempts to make a low temperature coke had been tried in various parts of the country—technically with some success but commercially without any great success. In the meantime, however, it was necessary to find a fuel which the people could burn in their grates and which would be as far as possible smokeless. There was another method of approaching the problem. Mrs. Fishenden had pointed out that we had one fuel as a substitute for coal—that was gas-coke. Why not adjust our grates to suit this fuel, instead of adjusting the fuel to the grate?

A VISITOR suggested that one way to educate the people in the advantages of smoke abatement was to introduce the subject into the elementary schools and appeal to the children on the desirability of clean homes. The attitude of the people at present was that they did not believe in "spending first and reaping afterwards." He thought that the schools offered great possibilities in this direction.

Dr. DES VOEUX (London) said that the paper by Mr. Simon and Miss FitzGerald had shown them the enormous progress that had been made on a large scale in housing schemes for the reduction of the smoke nuisance. He would like to move that the paper should be sent to the Ministry of Health for their information. The Ministry

should be given the opportunity to learn what had been going on in that direction, and perhaps it would induce them to agree to some modification of the Bill which had been read a second time, and which during the autumn would come before a committee of the House of Commons. He would like to move further that that meeting should back up the efforts that had been made by the Coal Smoke Abatement Society to procure an amendment to Clause 5 in the Bill. This clause, in its present form, ordained that the local authority should have power to make bye-laws requiring the provision in new buildings, "other than private dwelling houses," of such arrangements for heating as were calculated to prevent or reduce the emission of smoke.

If that clause passed, nothing was going to be done to support the 143 public authorities who had already done something in the right direction. While the Ministry of Health were under the delusion (as he had proved they were through recent enquiries) that only seven authorities were interested in the problem, he could understand why they put that clause in in its present form. He was going to move the following resolution :—

"That a communication be sent to the Minister of Health begging him to remove from Clause 5 of the Smoke Abatement Bill the words, 'other than private dwelling houses' ; and to give urban authorities the power to make bye-laws requiring the provision in new buildings, including private dwelling houses, of such arrangements for heating and cooking as were calculated to reduce or prevent the emission of smoke."

Objection was raised that Dr. Des Voeux was out of order, but at the suggestion of the Chairman, Sir Napier Shaw, that the resolution should take the form of a recommendation from the conference to the Executive Committee, who should be asked to pass it on to the Government if they thought fit, it was seconded by Mr. Graham and passed unanimously.

Miss Marion FitzGerald, replying, thought that Dr. Fishenden had raised a very important point when she said some modern cooking grates might be nearly as wasteful in use as the old-fashioned Yorkshire range, and she was glad to hear that scientific tests were to be made. She herself was accumulating some useful comparisons by getting people using different types of grates to keep careful records of the amount of fuel used and the amount of cooking and water heating done.

She considered Dr. Banks' suggestion to approach the big building societies a very useful one, and she thought the League should make a point of getting in touch with them.

Mr. Pointon Taylor, replying, said he could hardly agree with Dr. Owens with regard to his deduction on the "commonsense" application of zoning. If they could by any chance place all the factories of London on the leeward side of the city, so that the smoke would be blown outwards by the prevailing winds, he would prefer to have it that way for the large number of days concerned throughout the year in exchange for the smaller number of days when non-prevailing winds might, as stated, cause fogs.

In connection with the proposed amendment to Clause 5 of the Smoke Abatement Bill, perhaps those sufficiently interested might for a moment imagine the clause amended as they desired, and then assume themselves in the position of a local authority who had been given the power to make bye-laws on the subject by the passing of the Bill. He thought that under existing circumstances they would not find the making of suitable bye-laws, which must set out in clear terms precisely what the builder must do to comply with them, a very easy matter. Nevertheless he thought that some suggestions for model bye-laws would be helpful when considering the proposed amendment.

As for the attitude of the Ministry of Health they probably all knew that anything which bore relation to capital costs or working costs of housing or anything that might, even by its psychological effect, act as a deterring influence on the production of houses was a very serious matter for consideration. It should be borne in mind that perhaps they were more than ever in the immediate future concerned in the housing of the poorest classes of the community, and building costs, and what affected them were matters of great importance when the present and future house building programme was borne in mind.

He thought that they all realised the sympathetic attitude of the Minister of Health and the Ministry generally to the smoke abatement question, but it had to be considered in relation to the prevailing circumstances.

Sir Napier Shaw, returning the thanks of the meeting to the authors of the two papers, said it seemed certain to him that we should have to evolve an entirely new state of affairs in this country if we were to carry on the industries of the country. Briefly, in the future, coal must be distilled before it was burned. That, in effect, was the finding of the Coal Commission. The coal industry of the country would not be in a profitable condition for many years to come. The economic situation was such as we had never faced before. For this reason, so far as he could see, the time was not exactly opportune for formulating recommendations. Things which might have been recommended before the present state of affairs in the coal industry were not necessarily the recommendations which the League would want to put forward now, or in the near future. Thus it might be found necessary strongly to recommend the use of electricity primarily as a means of utilising the gas produced by the distillation of coal. In the meantime he would like to say that some Government offices were not exactly examples of what to do from the point of view of the smoke difficulty. Mr. Pointon Taylor might remember being a fellow-member of a deputation with himself to the Ministry of Health. On that occasion it was really difficult to see the Minister of Health on account of the smoke that came from the fireplace of the room in which he received them. It was one of those things that pass without comment. A coal fire smoking while they were talking about reducing the smoke nuisance. Meantime, before one could see a way clear to formulating the recommendations which would commend themselves to the whole community in face of the economic situation, they might do worse than remember the old proverb (particularly with regard to the Government department he had men-

tioned) that "example is better than precept." They might take the same view with regard to the many operations and experiments that local authorities had conducted. He felt quite certain that if in all these cases they kept the proverb in mind they would find the way paved, when the time came to make recommendations, for an easy assent to the ideal of smokeless municipal houses, and their object would be achieved.

Third Session of the Conference

HOUSING *and* SMOKE ABATMENT

HELD IN THE

CONFERENCE ROOM, BINGLEY HALL,

Wednesday, September 8th, 1926.

Chairman: Dr. DES VOEUX, Treasurer, Coal Smoke Abatement Society.

Dr. DES VOEUX, in opening the proceedings, expressed the hope that the importance of the domestic grate as a cause of air pollution would be insisted on. The Coal Smoke Abatement Society, as early as 1902, conducted tests on ordinary domestic grates. The number in the first series tested was small because few manufacturers in those days were interested in improving the design of grates, which could only be achieved by careful examination and report. The tests were made in a Government office in Whitehall, and he believed that only six grates were tested. The result created such a stir that a year or so later there was a demand from manufacturers for a more comprehensive series which were carried out in December, 1905, and January, 1906, and about sixty grates were tested. A long report on the tests, published in the "Lancet," created a large amount of interest. Following the publication of the report they were asked to conduct another series of tests. Again, in 1906, was an elaborate test made on gas fires. The Government came to their assistance, and gave them the whole of the second floor of the new Government buildings at the corner of Whitehall. The results of the tests, which lasted over a week, was published in a long and elaborate report in the "Lancet" on May 19th, 1906, and created much stir amongst manufacturers. The result was great improvement in the design of the ordinary coal grate. He thought he might say that proof was forthcoming that no grate, at that time, designed to burn bituminous coal, eliminated smoke. Some grates were, of course, better than others, but all were sinners. The conclusion they came to was that if it was wanted to get rid of smoke from the domestic grate they must have some other means than improvement in design at their disposal. This meant that bituminous coal would always emit smoke if burnt in an open grate, and other fuels must be found. We had not reached that time yet. He hoped, however, that that day was in sight because public opinion was arising and demanding that the air of our cities should be free from those noxious fumes from which we had suffered for so many years.

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VENTILATION AND HEATING.

Dr. Leonard Hill, M.B., F.R.S. (Director, Department of Applied Physiology, National Institute of Medical Research), read a paper on "Ventilation and Heating."

VENTILATION AND HEATING

by Dr. LEONARD HILL, M.B., F.R.S. (Dirctor, Department of Applied Physiology, National Institute of Medical Research).

The ideal method of heating and ventilating is afforded by the sun and a cool breeze on a spring day. The ground is warmed by the sun, and the body by radiant heat from it, and from the sun and sky shine. The feet are kept warm by the ground where the air is still, while a cool breeze plays round the head. The ultra-violet rays of the sun and sky shine act beneficially upon the naked parts of the body, while the cooling power of the moving air suffices to promote loss of body heat by convection and evaporation, and stimulate activity. There is no monotony. The opposite of these excellent conditions is given by a shut up room, with cold walls and draughty floor giving cold feet, the room being heated by a flueless stove, giving off dark heat, and warming the air which surrounds the head while contaminating it with sulphur acids and other products of combustion. The imitation of the ideal outdoor conditions in a small room is very difficult but best afforded by a luminous service of energy such as a gas fire or a coal fire, giving sufficient radiant energy to warm the body comfortably, while the window is kept open sufficiently to keep the air gently moving. Commendable, too, is a system of heating which warms large areas of the walls, floor or ceiling to a very moderate temperature, *e.g.*, 80-90° F., combined with open window or extract fan ventilation. In winter, holidays in sunlit places or arc light baths in cities, are required to make up for the lack of invisible ultra-violet rays suffered by sedentary indoor people. The good effects of heating by a visible source of rays has been shown in the London Zoo where marmoset monkeys and iguana lizards have been kept alive and healthy through the winter by the use of incandescent lamps placed close above the animals. Dark heat has never sufficed for these animals. They require the rays to penetrate the skin and warm their tissues.

We want to breathe cool air which even when damp holds very little water vapour ; the evaporative loss from the lungs is then considerable when this air is warmed up as it is to about 33° C. (the temperature of the expired air) and saturated. On an adequate evaporative loss from the breathing tubes depends an adequate flow of blood and lymph through the living membrane ; this enhances the defence against catarrhal disease. On the adequate cooling of the body by moving air depends the adequate loss and production of the body heat, the utilisation of food, the appetite and good digestion, the tone of the muscles and efficiency for work, etc. An adequate exposure of the skin to ultra-violet rays helps to maintain the general health, vigour and happiness. Sedentary life spent in dim but artificially heated air combined with

over-clothing, over-heating and lack of exercise depress the health and enhance catarrhal diseases and nervous troubles.

The observations made by the acetene meltylene blue method of measuring the ultra-violet rays have shown us that two-thirds of these rays are lost through pollution of the atmosphere by smoke and dust in the city of London compared with a clean country place. We know that rickets are caused by a deficiency of both diet and light. It has recently been discovered that the ultra-violet rays can activate cholesterol which is present in animal and phylosterol in vegetable tissues and endow these with the property of an antirachitic vitamin. It is the want of this vitamin and of a proper balance of salts of calcium and phosphorus in the diet which causes rickets. The vitamin helps in the absorption from the gut and utilisation of these salts for bone building. Exposure to ultra-violet rays is one of the simplest methods of prevention of rickets and can in part make up for the deficiency in the quality of the diet which so many poor children suffer from. So too, tuberculosis is a disease arising from bad housing, from confined dark and stagnant air coupled with ill feeding and over fatigue. It is prevented by the open air life afforded in Sanatoria, and the children of tubercular parents at such a colony as Papworth living the open air life wholly escape infection in spite of exposure to the tubercle bacilli coughed out by their patients and grow up strong and healthy.

We want people to realise the immense importance of exposure to open air and sunshine, and the mischief of coddling indoors in overheated and draughtless rooms, of over clothing and over feeding, and of choosing the wrong foods, viz., those artificially impoverished by the methods of the miller, refiner, canner and cook. We want to purify the air of the filthy smoke pollution which curses our cities, cutting off ultra-violet rays, warmth and light, destroying green foods, the great primary source of vitamines, making filthy and dismal the streets and parks and driving people away from health-giving outdoor exercise into unhealthy sedentary indoor amusements and causing vast economic loss by destroying building stone, metals, decorations, by dirtying clothes, by obstructing locomotion by smoke fogs and by entailing artificial lighting.

The great cause of smoke pollution is the domestic fire. The British love an open fire and rightly because it suits the changeable climate. Britain is very rarely exposed to a period of intense prolonged cold in winter, and the British do not secure outdoors the sun baths provided in continental or North American winters. The British weather changes so rapidly that one day it is cold and the next day mild and muggy ; and such changes occur even in a few hours time. We want then an elastic system of heating, not plenum central or stove heating with windows all sealed up, but a fire which can be made up or let down and an open window which can be easily adjusted to our feelings. We should put on an extra garment indoors rather than shut a window. An overcoat should be used for this purpose and not for reducing our desire for active exercise out of doors.

The cold damp of our climate makes the comfort of the radiant heat of a fire

great. But we can secure the fire while abolishing the smoke pollution by a gas or electric fire or by some smokeless fuel such as coke which is available and cheap. Electric fires are excellent, although at present economically unsound, as the waste of the energy of the coal used in producing electricity is very great. Unlike Switzerland and Italy we have cheap water power available for producing electricity only in very few districts. The distillation of soft coal with the production of coke, gas and all the valuable by-products is economically right, and coke and gas should be used not only domestically but for raising steam and electrical power. The distillation of coal affords motor fuel, high explosives, dye stuffs, valuable chemicals and, instead of destroying green food with sulphur acid fumes, it yields a valuable fertiliser ammonium sulphate which takes the place of nitrates from Chili. To wait for reform till some smokeless fuel other than coke is produced is bad policy. The highest experts tell us that such is most difficult to produce economically, while the production of gas and coke has been economically established.

Let us not then put off the demand for abolition of smoke pollution on the plea of waiting for the economic production of a smokeless fuel better than coke and gas. The modern gas fire has been perfected so as to give a maximum of radient energy including visible red rays which penetrate the skin and the tissues to some depth, and change over their energy within the tissues and are thus superior to dark heat rays which penetrate less and warm the surface layer of the body more. The modern gas fire is a fairly efficient ventilator ; the second opening into the flue now provided in the best stoves takes some extra 1,000 cubic feet of air an hour out of a small shut up room thus raising the total ventilation to some 3,000 cubic feet per hour. The radiant energy of a gas fire, however, is so great that a window can and should always be kept open. The gas fire requires to be controlled by use of few or several radiants so as to prevent overheating which is a common mistake. To arrange coal fires in gas grates is an inefficient and uneconomical plan. The gas fire as now constructed after much scientific research is built on lines which afford the maximum radiation at least cost and secure removal of all fumes up the flue. The dislike of gas fires is due to bad design and escape of fumes and overheating by want of control of the fire and lack of window ventilation. No flueless gas fires should be used in closed rooms, especially in such rooms as are more or less sealed up from free ventilation. In using cooking stoves, gas rings and gas fires a window should always be open a little, and then any danger of carbon monoxide poisoning arising from leakage of gas is removed.

It will be a great advance if catalysers recently discovered can be generally brought into use in gas plants and the poisonous carbon monoxide converted into methane, and so do away with the danger of gas leaks. The slightest smell of gas should be taken as a warning and no leakage allowed to continue from any gas pipe or fittings. The risk of carbon monoxide escaping in poisonous amounts from properly flued gas fires is nil, and from flueless stoves, gas rings and kitcheners, when in use, very small and entirely preventable by the open window. Carbon monoxide acts as a

poison by displacing oxygen out of the haemoglobin of the blood and as it has some 250 times the affinity for haemoglobin which oxygen has, a concentration in the air of as little as 0.1 per cent. is unsafe. By the use of oxygen for breathing it can be driven out of the blood again, and this is the great means of resuscitating the poisoned. The bad effect on health of flueless stoves is due far more to heated stagnant air of shut up rooms than to fumes. The cost of a gas fire lit when wanted, and turned out at other times, may be, and generally is, no greater than that of a coal fire which is kept in all day, and then the gas fire saves all the expense and trouble of lighting and making up a coal fire, of bringing of coal to and removal of ash from it, also it saves the damage done to decorations, etc., by the dirt of a coal fire.

In these days when service is difficult to obtain the gas fire and cooker become more and more popular. An electric fire and cooker may be run economically by good management and strict curtailment of use only when needed. Our climate allows such saving to be effected and it will be effected as the belief in the healthiness of cool open air conditions spreads. How great in the past has been the waste through keeping coal fires in all day during warm winter days. While the gas fire is admirable for house rooms, the coke boiler is most economical for heating water and one of these installed in the kitchen supplies ample hot water for baths, washing, etc., while burning up all refuse and warming the kitchen as is needful when cooking by gas, and moreover it helps to warm and dry the whole house by the warm air passing upwards from it, thus affording a most valuable and simple method of central heating supplying all that is needed in our climate for an ordinary small house, where individual rooms are fitted with gas fires.

For schools, offices and workshops the best method of heating is by large surfaces of wall, floor or ceiling heated to a very moderate temperature, *i.e.*, under 100° F., so that the body loses little heat by radiation to those big warm areas. This heating can be carried out by pipes embedded in the concrete after being tested beforehand to several atmosphere pressures. At the Bush building at the end of Kingsway the walls are so heated, and the air is kept cool and fresh, windows being opened as required and gas fires used where any extra coal heat is needed. The furnaces are heated by oil and the furnace room is as clean, cool and bright as any part of the building and the work of the engineer pleasant and easy. In some installations hot air is used in pipes embedded in a concrete floor resembling the Roman hypocaust. The hot air can be quickly driven out and replaced by cool air by means of fans. When the weather changes from cold to warm, this affords a most valuable means of adjustment for our changeable climate. The essential principle should be to avoid heating the air and secure a sufficient movement of cool fresh air round the body while warming the body by radiant heat, and this can be effected by the above means without any pollution of the atmosphere with smoke. Where plenum systems are employed in Washington schools loss of time from catarrhal complaints has been found to be far greater, over six times greater on the average, than in schools ventilated by open windows. In buildings where steam pipes or coils are used for heating, extract fans

should be employed for ventilation and the pipes should be heated most at night so as to warm the structure of the building and the heat cut down, or altogether off, by day. If a house is warmed by night by steam coils and the heat cut off and the sitting rooms and the windows thrown open in the morning excellent conditions are secured—warm walls and cool fresh air. Wise management on these lines can effect a great deal. For all places where much heat is used for manufacturing processes and particularly for warm moist places, fans are required to cool the bodies of the workers by the movement of the air and so keep up efficiency and contentment.

THE SMOKE EVIL: A WOMAN'S POINT OF VIEW.

Mrs. Cloudesley Brereton, taking the place of Mrs. Peel, who was indisposed, dealt with the question from the woman's point of view under the two headings: "What smoke abatement does for women," and "What women can do for smoke abatement." She referred to the words Professor Hill had used in describing the causes of tuberculosis—"bad housing; confined, dark and stagnant air coupled with ill-feeding and over fatigue." These were the evils that had to be overcome; these the matters to which women's attention was turned.

The speaker discussed the types of remedy at hand—and shown in the exhibition—designed to meet these problems and to relieve women of the burdens imposed upon them. But it had to be remembered that the problem for 80 per cent. at least was that of running a home in houses built in other days for other circumstances. The conversion and re-equipment of the large Victorian house was not being handled in all cases with good judgment. The fatigue of staircases was often forgotten by the architect or builder; how much more often was the importance of good planning within the kitchen overlooked? Yet these were things that mattered to the mother and the wife.

Fashion was not always the fault of those who followed it. The fashion of bad methods (including the use of raw coal) in running a house was not always the fault of the housewife. Too often the blame must be attributed to the unsuitable equipment and arrangements with which the woman found herself saddled. But women were themselves in advance of this state of affairs—in advance, be it added, of smoke abatement legislation. The speaker had recently presided over a committee responsible for judging many thousands of children's essays on, among other things, domestic economy. She had been struck by the grasp which these children from ordinary elementary schools had shown of the proper way to run a house. It was a hopeful sign that the coming generation was being trained to see that the conditions of to-day must be improved upon. It was a hopeful sign that the women's pages in the press were more and more concerned with topics other than dress, reflecting the desire for better homes—for the removal of those evils which Professor Hill had named. The same was true of women's magazines. There was a lot of propaganda to be done, and these were only some of the forms it could take and was taking.

Women themselves could help smoke abatement by their own strong influence. Women had the vote and souls of their own. They were in a position of greater responsibility if they cared to exercise it. The care of infants and maternity questions were bound up in this question of pure air. Women could, by the weight of their own solidarity on a particular question, bring about many reforms. They could determine, if they willed what they wanted, in the matter of housing and in the equipment of the houses. They could influence local councils, and in the same way by collective action influence politicians. Again, a woman who could afford so to equip her house that it would be smokeless, would be doing an admirable public work in the sense that she would be setting a useful fashion. Women who were able to do something in the direction of influencing public opinion should try and think of the 75 per cent. of women who were obliged to have only that type of accommodation which was given to them. What was wanted was the creation of a public opinion. Public bodies usually yielded to public opinion if it were strong enough ; they were hardly ever in advance of it. If we could set the fashion regarding smoke elimination we should go a long way towards securing the great reform desired. Builders would bring their places up to date ; architects would design upon the lines that all desired. We had to put up with undesirable things because we made no effort to get them altered. This matter was largely in our own hands, and is certainly capable of being remedied.

DISCUSSION.

Mr. W. W. Nobbs said he was in agreement with almost everything Mrs. Cloudesley Brereton had said. Some of the points that Dr. Hill had made had created an impression on his mind, and would, he thought, affect considerations in his professional practice. With regard to the ultra-violet rays, he would like to know whether the period representing a definite intensity of radiation was over twenty-four hours.

Dr. Hill : Over twenty-four hours.

Mr. Nobbs enquired if it were possible to get the ultra-violet rays without the use of the arc lamp. Could they be obtained from any of the practical forms of heating from a gas, electric or coal fire, or from a mercury vapour lamp ?

Dr. Hill replied that he included the mercury vapour lamp as an arc lamp. It would give off the ultra-violet rays, the strength of the ultra-violet rays depending upon the energy you put through the arc. Distance accounted for variation in strength, the intensity falling off approximately as the square of distance from the arc. No gas or gas lamp gave off the ultra-violet ray, at any rate, in any measurable amount. There must be high temperature such as an arc gave. As to whether he should advocate apparatus for affording ultra-violet rays, his view was that there should be facilities for arc light baths, just as there were for water baths.

Dr. Ferguson (Medical Officer of Health, Smethwick) said that despite the efforts of the Smoke Abatement League it would be some considerable time before our great towns would be freed from the effects of domestic and factory smoke. In the

meantime something might be done which would counteract the tendency to rickets amongst children in our great industrial towns, who were robbed of the natural preventive rays by smoky atmosphere. The use of ultra-violet radiation afforded an easy and efficient means, and he was strongly of opinion that it would be possible practically to abolish rickets through the agency of light clinics. About two years ago they established a clinic in Smethwick, and the results had been most encouraging. The installations were not expensive, and large numbers of children could be dealt with quite successfully. He did not think rickets would be likely to occur if they could irradiate babies in the first twelve months of life.

Great attention had been paid to the gas fire, but whilst it was very effective it did not appeal to everybody, and he was very much impressed by the possibilities of smokeless coke which they had seen burning in an open grate. This fire had been evolved by the genius of Dr. Owen, and in his opinion was the nearest approach to the perfect coke fire which was seen in the workman's bucket perforated with holes. He thought every delegate should see this fire, and those interested in housing schemes should consider its adoption.

The meeting terminated with a unanimous vote of thanks to the speakers.

Fourth Session of the Conference

SMOKELESS HEAT AND POWER

HELD IN THE

CONFERENCE ROOM, BINGLEY HALL,

Thursday, September 9th, 1926.

Chairman : Dr. E. W. SMITH, Hon. Secretary, Fuel Section, Society of Chemical Industry.

Dr. SMITH said they had Dr. Fishenden to address them. She had very kindly accepted the invitation of the Fuel Section of the Society of Chemical Industry to represent them at the conference. Dr. Fishenden was a member of the Fuel Research Board, and she would present a paper on "The Outlook for Smokeless Domestic Heating." They ought to make a note in their minds that Dr. Fishenden was the first female technological fuel expert in this country. They, doubtless, all knew of the work she did at Manchester a few years ago, and he was pleased to say that her example was being followed by others in the Universities of Leeds and Manchester, who were making a speciality of this subject of fuel.

Before calling on Dr. Fishenden there was a point he wished to mention. During the week they had had their attention drawn to the fact that in spite of the enormous extension in the use of electricity and gas for domestic purposes, and in spite of the fact that in all the large cities and in London, the smoke nuisance was being abated ; the official records showed that there had been practically no reduction in the use of coal for domestic purposes. There was about forty million tons of coal being used for domestic purposes per year. This was the case many years ago. There could be only one conclusion—that coal was being used more efficiently. It was worth while looking into this question and trying to discover where it was being used most efficiently for domestic purposes. It seemed clear that with the rapid extension of the semi-well, well, fire-bricked and sloping-backed grates, people were using their grates more efficiently, too, and that the smoke nuisance from that source was being to some extent abated. However, there was still a great field for activity in the whole and total elimination of the nuisance. He would call on Dr. Fishenden to read her paper.

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The Outlook for Smokeless Domestic Heating

By MARGARET FISHENDEN, D.Sc., F.Inst.P., Fuel Research Division, Department of Scientific and Industrial Research (for the Fuel Section of the Society of Chemical Industry).

In England, the first documentary evidence of acquaintance with the use of coal is to be found in the year 853 A.D. in the Saxon chronicle of the Abbey of Peterborough ; but tools and cinders which have revealed themselves in the course of excavating operations in the neighbourhood of the Roman wall indicate that the Britons were already familiar with this fuel at a much earlier period.

In these old days, however, and for long afterwards, wood was the general fuel. No great art was observed in its use. Fires were simply piled up in the open air or perhaps at the mouth of a cave ; and later, when man had gathered into groups and had learned to build huts or houses, the same rude habit was followed. A shallow hole or pit, or a flat stone, formed a hearth in the middle of the floor, the smoke finding its way out as best it might through unglazed windows or a hole in the roof. But as the population of the country multiplied and big towns sprang up, the great forests gradually dwindled before the growing agricultural requirements of the people, and wood became increasingly scarcer and dearer.

Such a situation naturally favoured an extension of the use of coal, and so rapidly did it gain ground in London that, notwithstanding a succession of enactments forbidding its adoption on the grounds of "its noisome smell" and "the unsavoury vapours therefrom," it soon became a common fuel, especially in the arts and manufactures. By 1662 it had become so far popularised that Charles II. was able to raise the enormous sum of £200,000 by means of his famous "Hearth Tax." But even so, the total annual coal production of the United Kingdom at this time, which has been estimated at some two million tons, sinks into relative insignificance before the vast outputs of more recent years.

When, in the 18th and 19th centuries, metals began to be worked in quantities hitherto unthought of, the production of coal received a great impetus. Canals were constructed to carry it to new districts, and it soon became the general fuel of the nation, both for industrial and domestic purposes. It is, indeed, well known that the rapid rise in the industrial position of Great Britain during the 19th century was largely to be ascribed to her abundant supplies of coal, and to the low prices at which it could be produced ; while the present commercial age in general owes its development in the main to the exploitation of the world's great coalfields. And although in some places it has been possible to take advantage of natural oil or of water power, the vast demands for artificial heat, artificial light and mechanical power which have grown up in recent years are still met almost exclusively by the use of coal or of its derivatives.

Throughout the 19th century, and until the incidence of abnormal war and post-war conditions, the coal production of Great Britain rose steadily from about 10 million

tons in 1800 to a maximum of 287 million tons in 1913. After a temporary decrease for the reasons mentioned, to 230 million tons in 1920, the output had risen to 267 million tons in 1924, of which more than 80 million tons was exported. Since then, of course, owing to a depression in the world's demand for coal and to labour troubles in the mines, the output has again fallen, and conditions in the industry have been very unstable. As was pointed out by the Permanent Under-Secretary for Mines in evidence before the Coal Commission, "ever since the end of 1920 the depression that then overtook the other heavy industries has been lying in wait for the coal-mining industry, but has been warded off by a series of accidents. For the last half of 1921, the industry was busy filling the gaps made by the three months stoppage in the summer of that year. In the first half of 1922, the depression actually laid its hand on the coal-mining industry, but the great strike in the United States of America came to our rescue. After that came the French occupation of the Ruhr, and it is only during the last fifteen months that the industry has not been helped by the temporary cessation of some normal sources of coal supplies. Without this its present difficulties could hardly have failed to come upon it four years earlier."

Great Britain is one of the world's most important coal producing areas. But while fifty years ago our output represented about one-half the total world output, in 1924, owing to the increased production of other countries, and particularly of America, it had fallen to no more than one-fifth of the world's total. Further, vast resources of water power and of liquid fuel have been tapped in other countries ; but in Great Britain, where water power resources capable of economic development are very limited, and where natural oil is practically non-existent, coal and its derivatives must probably for a long period be relied upon as the major source of energy for all purposes.

Unfortunately, in the past, largely owing to its cheapness, coal has been used with great prodigality ; and as a result, in spite of the steady progress in methods of combustion which has been effected in more recent years, inefficient methods and inefficient plant are still in many cases in use. In face of present day competition, however, the necessity for utilising our coal supplies with the utmost possible efficiency is of primary importance if we are to retain our prosperity and hold the industrial field successfully against other nations.

Since the production of smoke is evidence of incomplete combustion, the general problem of efficient fuel utilisation largely embraces the more special problem of smoke abatement. The greater proportion of the coal which is raised in this country is of a soft, bituminous nature, and contains a high proportion of volatile, or gaseous, matter. When such coal is burned in its natural or "raw" state, it is subject to decomposition and distillation at temperatures below the ignition point, with the result that its use is accompanied by the production—to a greater or lesser degree according to the conditions—of unburned volatile products, soot and tarry matter. These find their way into the atmosphere and are worse than wasted, since they are the cause of very serious damage ; but were they recovered, they would yield under suitable treatment a great diversity of useful commodities such as dyes, drugs, disinfectants, fertilisers, perfumes, etc.

Of the coal which is used for industrial purposes in this country by far the greater part is burned in boiler furnaces for the production of steam. For this object, except in certain special cases, gas or electricity has few advantages over coal, since by the application of up-to-date scientific principles, efficiences as high as 80 to 90 per cent. can be achieved from solid fuel installations. In comparison with such performances, either gas or electricity, even on an assumed efficiency in use of 100 per cent., would not only be costly to the consumer but its production would entail an expenditure of coal heavy in relation to the direct use of solid fuel. The average efficiency of the existing boiler plant in the country, however, is certainly below 70 per cent., and it is clearly of great importance both in the interests of fuel economy and smoke abatement that this figure should be substantially improved upon. This field also should offer an increasing outlet for coke since practical experiment has shown that coke is very suitable for steam raising requirements, especially for low rates of steaming.

For furnace work and other general industrial heating purposes the comparison is more involved, since the relative efficiencies of utilisation of the different forms of energy are difficult to compute, or in many cases unknown. But there is little doubt that although the actual running costs of energy brought as gas or electricity may frequently considerably exceed the corresponding bill for coal sufficient to perform equivalent services, its adoption may in many cases be advantageous. To the owner of an industrial concern, both initial cost of fuel and such questions as national coal conservation are matters which must take their place among numerous other considerations. The fuel bill is usually a small proportion of the total production costs, and the primary aim of the manufacturer will naturally be to carry out at the lowest possible expense, compatible with satisfactory results, the necessary operations which lead to the finished article. And in the realisation of this ideal the initial price of his heat units per therm will be only one governing factor among many. Thus, for example, although, as will be shown later, the price of a therm in electricity or gas is usually much higher than the price of a therm in coal or coke, if its use should entail a reduction in labour costs, or make possible a more accurate focussing of the heat produced upon the place where it is required ; or if it should be instrumental in creating a better (*i.e.*, more valuable) product, it would be commercially sound to use it in preference to a cheaper fuel.

Coals with low volatile contents are largely absorbed for steam raising purposes; but in any case, as we have seen, the efficiencies reached in modern boiler installations are very high, and when due attention is paid to the application of known scientific principles, the fuel can be burned with relatively little smoke production. Most of our domestic coal supplies, on the other hand, are drawn from bituminous seams, and if evidence of the extent to which the volatile constituents of the coal escape combustion were needed, it is plainly afforded by our smoky chimneys. Indeed, in such a haphazard and unscientific manner is household coal used that it is responsible for far more than its proportionate share of smoke and soot. The domestic consumption of coal has

risen to about 40 million tons a year, the industrial consumption to some 100 million tons ; but in spite of the difference between these figures, there is good reason for believing that the house chimney is the more mischievous, and if the problem of the domestic fire could be solved satisfactorily, the way to smokeless cities would become relatively easy.

It has of late repeatedly been stated that on account of the escape of by-products and of their contaminating effects upon the air into which they emerge, the burning of bituminous coal in its raw state should be altogether discontinued, the proper course being first to subject it to some form of preliminary treatment whereby the distillation products might be conserved and the smoke producing constituents thus eliminated, or whereby it might be transformed into some form of energy which can be utilised without smoke emission. Many such processes are available whereby coal can be converted more or less completely into gas, coke and oils in various proportions, or into electrical energy ; but their development must naturally be dependent upon the commercial possibilities which are presented.

At the present time the most important of such processes are included in electricity generation and in the various systems of carbonisation. But recently, methods for the liquefaction of coal (the Bergius process) and for the conversion of water gas, produced from coke, into liquid fuels, have come into prominence ; and although these have not yet been developed commercially, their possibilities in regard to future oil production are of great interest. Such innovations cannot, however, be dealt with in detail on this occasion.

It must be borne in mind that in any transformation process whereby energy is converted from one form into another, a thermal loss is inevitable, or, in other words, that even under the most favourable conditions possible, the potential heat producing capacity of carbonisation products or of electricity falls short of the original heat value of the parent coal. The deficiency may, however, in certain circumstances subsequently be counterbalanced, or more than counterbalanced, owing to the fact that the new form of energy may, and in most cases can, be utilised with a greater efficiency than is possible when coal is burned directly in its natural state. But its immediate effect is to increase the price of either gas, oil or electricity in relation to the price of coal, since the return which they give must compensate the undertaking for the thermal losses occasioned in the course of their production, in addition to meeting overhead and labour costs and reasonable interest or capital invested. If by such processes as blending, which will be spoken of later, the low value colliery products can be converted into high value carbonisation or other products, the above expenses can often readily be met.

Of all forms of energy into which the potential heat of coal can be converted, electricity is the most convenient on account of its cleanliness, adaptability and ease of control ; but, unfortunately, it is also that form of energy in the production of which the wastage of the heat of the coal is most serious. The mechanical power necessary for driving the dynamos by which electricity is generated is derived from the heat liberated by the consumption of coal. The initial step is to burn the coal for the

production of steam, and in this process, provided that the best modern practice is observed, efficiencies as high as 80 to 85 per cent or even more are obtainable, and smoke production is reduced to a minimum, although not entirely absent. But with so low an efficiency can the steam be utilised for the subsequent operation of producing mechanical power, that although the last step of converting mechanical power into electricity involves little further loss, the overall thermal efficiency of the generation of electricity from coal in the power stations of the country averages only about 13 per cent., that of the best stations rising to 20 per cent. On the basis of initial thermal expenditure in coal, therefore, the maximum possible efficiency of any process using electricity as a source of energy is 20 per cent. for the most efficient generating plant or 13 per cent. as an average for the country as a whole. Low grade and comparatively cheap coal, however, such as would be of little value for any other purpose, can be utilised for the production of electricity in large power stations ; but since the available supplies of such coals are limited, any very considerable development of power production might involve the necessity of falling back upon more costly raw material.

Since the by-products of the coal are not recovered in the process of power generation, it is clear that the main product, the electrical energy itself must be the sole source of income, and that the revenue obtained from it must cover both expenditure and profits. In view of the low thermal efficiency of its production it is thus inevitable that the price of electrical energy, calculated upon its potential heat producing capacity, should be very high. The relatively cheap rate at which the inferior coal used can be purchased tends to counterbalance to some extent the reduction in the thermal value of the product, but is far from being able completely to compensate for it. As a result, electricity for heating or cooking purposes generally costs the householder about 59d. per therm (2d. per Board of Trade unit), while a high grade household coal can be procured for 1.7 to 2.1d. per therm (45 to 55 shillings per ton).

In some cases, however, special facilities are offered to the domestic consumer of electricity. Owing to the fact that electrical energy cannot easily be stored as such, plant of size sufficient to deal with the maximum demand must be installed in any area. It is thus obviously of great importance to power undertakings to obtain as steady a demand, or "load," as possible, and so to avoid the necessity for generating during the course of a few hours only, a large proportion of their total daily output. Otherwise much of the capital invested is productive for only a small proportion of the total time. Electricity for domestic purposes is therefore sometimes offered at specially reduced rates, on the grounds that the energy used is likely to be well distributed, and help to improve the load factor (*i.e.*, the ratio of the electrical energy actually produced to the maximum production at full load). In other cases, power may be supplied very cheaply during certain specified hours, *i.e.*, during the hours of minimum load. A sliding scale usually allows of the large consumer obtaining his power at specially low rates.

Further, with a view to making electricity generally available at the lowest possible prices, the undertakings of the country have for the past five years been undergoing a gradual process of reorganisation at the hands of the Electricity Commissioners, who

were appointed on the recommendation of the Coal Conservation Committee ; and the formation of a Central Board empowered to develop a national scheme of transmission would follow the passing of the much discussed Electricity Supply Bill. For electricity, although it cannot be economically stored in quantity, can easily be carried without excessive loss over long distances from large central stations so equipped and run as to be economical in capital cost and maintenance and to yield the maximum possible thermal efficiency of generation. By such means it is hoped shortly to increase substantially the average efficiency of electricity production ; but there is no immediate prospect of its price, based upon potential heat producing capacity, approaching that of either solid, liquid or gaseous fuels, other than in very exceptional circumstances. However, as Sir John Snell pointed out in his recent sectional address before the Briitish Association : "An important result follows from widening an area of distribution—it enables supplies to be given from a common source to many industries, to railways and tramways, and all kinds of domestic and trade requirements. It is found by investigation that the maximum requirements of the various classes of consumer do not coincide in point of time, and, speaking generally, if all their maximum demands occurred simultaneously, no less than from two-and-a-half to three times the generating plant would be necessary to meet the load than is the case when their several supplies are drawn from one common source of generation. It is, in fact, only by supplying all the needs of a community within a large area from one common system that the maximum use can be made of the capital employed. When one remembers that the annual capital charges on a generating station represent some two-fifths of the total cost of generation, it will be seen how important it is to obtain the greatest use of the plant installed. . . . The *average* yearly load factor (on units *sold* by undertakings) throughout Great Britain to-day is under 25 per cent.—that is to say, the aggregate kilowatts required to meet the individual demands for hundreds of systems only produce one-quarter of the units possible were the plant working continuously." A reduction in price is most likely to be effected by reductions in the consumption of coal per unit generated and a reduction in capital expenditure. It was suggested by Sir John Snell that with coal delivered to the generating stations at 20 shillings per ton, electricity should in a few years be available for general domestic purposes, including lighting, at about 0.8d. per unit.

At the present time, about 8 million tons of coal, or only one-fifth the amount which is burned in domestic grates alone, or about 4 per cent. of the total home consumption, is dealt with annually in our power stations with the production of about 7,500 million Board of Trade units of electricity. Even the most optimistic forecast of the probable rate of expansion of supply undertakings would not lead us to expect any very appreciable immediate amelioration of the smoke nuisance through this agency. It has been stated that in the four years, 1921-2 to 1924-5, the average rate of growth has been 20 per cent. per annum, the growth of output for power having been 25.3 per cent. ; domestic supplies 27 per cent., and traction 12 per cent. per annum respectively.

Let us now pass for a moment to a consideration of other methods of coal treatment. By carbonisation is understood the heating of coal in closed retorts or ovens,

the volatile or gaseous constituents of the coal being driven off and led into suitable receptacles, while a solid residue, known as coke, remains. Carbonisation processes may be carried out either mainly for the production of gas, as at the gasworks for town's supply ; or mainly for the production of metallurgical coke for blast furnaces and other industrial uses, as in coke oven practice.

The gasworks process fulfils the conditions both of conservation of by products and production of smokeless fuels, namely, gas and coke. This desideratum, however, as we have already remarked, is not accomplished without cost. Some of the coke made must be reserved for heating the retorts, and there are slight leakages of gas both in manufacture and in distribution. Such causes represent an aggregate thermal loss equivalent to some 20 to 25 per cent. of the potential heat value of the coal treated. The thermal value of saleable gas does not as a rule exceed about 25 per cent., while saleable coke represents 45 to 50 per cent., and tar 5 per cent. For many purposes gas coke is a satisfactory substitute for raw coal, and if we assume that convenient outlets are to be found for all the coke produced, the effective weight of coal expended in the gas-making process may fairly be regarded as only about 50 to 55 per cent. of the actual amount dealt with, that is, as the total amount less available gas coke. Since on this basis of calculation, gas with a potential heat value of 25 therms may be considered as the return from a net expenditure of 50 to 55 therms in solid fuel, the thermal efficiency of the conversion of coal into gas becomes 45 to 50 per cent., or, taking account of tar, 50 to 55 per cent. These are the figures upon which must be based calculations of the inroads into our national fuel supplies consequent upon the substitution of town's gas for solid fuel.

By the injection of steam and air into the retorts during carbonisation, it is possible to gasify an increased proportion of the coal, with an accompanying reduction in the coke yield. The process may, indeed, be pushed to its limit, when the coal is completely gasified, no by-products other than a small quantity of tar being yielded. The overall thermal efficiency of the complete gasification process, however, is less than that of normal gasworks procedure, gas alone accounting for some 60 per cent. and tar for about 5 per cent. of the heat of the coal treated. Further, as more and more steaming is resorted to, not only does the volume of the gas produced increase out of all proportion to its thermal content, or, in other words, its calorific value per cubic foot rapidly decrease, but its specific gravity also rises. Since, however, energy in the gaseous form commands a high price per therm, and can be more efficiently applied than can solid fuel, it does not necessarily follow that the process of complete gasification is to be ruled out on the grounds of low thermal efficiency, especially as it is applicable to non-coking coals such as would not serve for ordinary gasworks purposes. The real test is the price per therm at which the gas can be produced ; and a lessened efficiency may be justified by the use of cheaper plant, elimination of labour, etc., but this method of carbonisation is not generally suitable for town's gas supply, particularly as the low calorific values and high specific gravity of the gas would necessitate the use of much larger mains or higher pressures than are at present required, and would entail a relatively heavy cost

of distribution per therm. And although the application of moderate steaming is now looked upon with more favour, and is being increasingly adopted in the gas industry, the experiments of the Research Sub-Committee of the Institution of Gas Engineers led them to the conclusion that complete gasification cannot be regarded as a commercial proposition with existing plant. For industrial requirements, gas of a much lower heat content per cubic foot than is usually supplied by gas undertakings can often be utilised satisfactorily. And it may in certain cases pay to instal plant for the manufacture of low grade gas on the premises, especially if it can be conveniently situated close to the point of application of the gas, and the length of pipe requisite for its transmission therefore reduced to a minimum.

Until lately, schemes involving the output of large volumes of gas of relatively low heating power were of little interest to the domestic consumer, but certain advances which have considerably modified the position, and chief among which should be mentioned the developments in regard to charging for gas by its heat content, instead of by its volume, have altered the position. For many years following the discovery of coal gas, its chief functions were limited to its possibilities as a lighting agent, and its value was determined chiefly by its illuminating qualities ; and for the protection of consumers, Parliament has from time to time imposed standards of intrinsic illuminating power, below which town's gas has not been permitted to fall. Recent years, however, have seen an enormous expansion of the use of gas for the production of power and heat, in comparison with which the amount employed for lighting purposes has become relatively small, though by no means insignificant. But even for illumination, the introduction and general adoption of the incandescent mantle, in which a delicate refractory fabric is *heated* to incandescence by gas, have removed the necessity for high illuminating powers of the gas flame itself. In addition, preliminary investigations have indicated that, with certain qualifications and reservations, the performance of gas-heated appliances, if these are suitably adjusted, is dependent rather upon the aggregate number of heat units in the gas consumed than upon the actual calorific value per cubic foot, or, as it were, the concentration of heat in the gas. As the slogan of the commercial gas world expresses it, "one B. Th. U. is as good as another." It has been pointed out by several investigators that this is not entirely true ; but generally speaking, a wide range of calorific value is permissible in gas for domestic use, without any appreciable detriment to its efficiency or convenience, so long as the burners are adjusted to the particular value which is to be supplied. Bearing in mind these facts, the Fuel Research Board in response to an enquiry from the Board of Trade, as to "the most suitable composition and quality of gas and the minimum pressure at which it should be generally supplied, having regard to the desirability of economy in the use of coal, the adequate recovery of by products and the purposes for which gas is now used," recommended that town's gas should be sold on the basis of its heat content. This recommendation was brought into effect by the Gas Regulation Act (1920), which laid down the unit of measurement as the therm, or 100,000 B. Th. U.

It will be realised that as in the majority of cases gas undertakings are commercial

concerns exposed to keen competition, economical results are likely to be ensured if they are given a reasonable amount of freedom, such as the Gas Regulation Act offers, since the quality of gas which any particular works can produce and supply most economically depends to a large extent upon the prevailing conditions. Undertakings are thus enabled to declare such a calorific value as will help them to meet the demands of their particular markets to the best advantage, for each centre of population and industry has its own special conditions and environment. And the decision as to the grade of gas to be produced most economically in any given case must depend not only upon the outlets, potential or developed, which exist for the principal product and its by products, but also upon the proximity of coal-fields, the types of coal available and their relative prices, and other factors.

In view of the high price which gas commands per therm in comparison with other fuels, it is not surprising that gasworks practice should, in general, have sought to increase the yield of the primary product, the gas itself, to the maximum extent compatible with the upkeep of a satisfactory standard of quality. As has already been stated, during recent years methods have tended in the direction of the more complete gasification of coal, of increasing the gaseous yield at the expense of the coke yield by introducing steam to the coal during the heating of the retorts, or of the separate production of water gas for admixture with higher grade straight coal yielded by normal carbonisation installations. No single method of production can be said to be generally most advantageous. Ferguson Bell, in his Presidential Address before the Institution of Gas Engineers in 1925, stated that "complete gasification has not, so far, fulfilled expectations. The low calorific value of the gas produced renders it unsuitable for general distribution over large areas ; and also the financial results compare unfavourably with other methods of carbonising where by products return anything from 50 to 80 per cent of the cost of coal used. It is suitable as an auxiliary to the coal-gas plant." And Samuel Tagg, occupying a similar position in the previous year, said that "as little or no immediate relief may be expected in the cost of standing charges, raw materials or labour, the prospect of further reductions in the price for gas(which is generally low in comparison either with pre-war prices or the cost of alternative sources of heat energy appears to lie in an extension of business, in increased values for the secondary product coke, and in higher production efficiencies and economies."

The consumer of gas is mainly interested in obtaining the maximum number of heat units at the lowest possible cost, however produced, and this there is little doubt the gas industry is making every endeavour to supply. The price of gas on a thermal basis, however, is high in relation to that of coal ; for the value of gas coke as a fuel is not at present such as to enable it generally to command a higher price than coal, and the gaseous product must, and can, bear the major proportion of such remaining costs of manufacture, etc. as are not covered by the sales of other by products. The current price of coal gas to the householder is about 8d. to 12d. per therm, while gas coke usually fetches some 35 to 45 shillings per ton—(1.5d. to 1.7d. therm) as compared with high grade coal at 45 to 55 shillings per ton —(1.7d.to 2.1d. per therm). The industry is a

very important one, and both the capital invested, which now exceeds £170,000,000, and the total quantities of gas made, are steadily increasing. The amount of coal carbonised per year by statutory and non-statutory undertakings agregates some 16-18 million tons, the gas produced exceeding 1,000 million therms.

The coke oven industry has grown up specifically for the manufacture of coke for metallurgical purposes, and particularly for use in blast furnaces. The solid fuel is thus in this case the primary product, and the chief aim is to produce coke which conforms to the necessary special requirements. Until comparatively recent years, no systematic attempts were made to recover the gas and tar produced, and they were commonly disposed of simply by burning them to waste. Latterly, however, it has been realised that the efficient utilisation of surplus gas is an important economic factor in the coke industry, and that it is worth while to recover the by-products so far as possible. A large proportion of the total tar output of the country is now derived from metallurgical coke works, and it has become usual to utilise the gas as a fuel wherever a suitable outlet can be found, or even in some cases to supply surplus gas to town's gas or electricity undertakings. The heating of the retorts is effected by gas. The yield of coke is about 12 or 13 cwt. per ton of coal carbonised, or thermally the equivalent of about 60 per cent, while tar again accounts for some 5 per cent., and disposable gas in up-to-date regenerative systems, for about 10 or 15 per cent. The overall thermal efficiency is thus closely comparable with that attained in other systems of carbonisation.

At the prices taken, *i.e.*, with coal at 50/- per ton, coke at 40/- per ton, gas at 10d. per therm and electricity at 2d. per unit, the costs of any given number of potential heat units are in the ratio of 1 : 0.8 : 5.3 : 31, while the amounts of coal involved in their production are in the corresponding ratio of 1 : 1 : 1.9 : 7:7. Since, however, it is never possible in practice to utilise the whole of the energy theoretically possible of generation from any source, but only a proportion which is far less for coal than for either gas or electricity ; or, in other words, since the "efficiency" of heating appliances adapted to the burning of coal is much inferior to that of gas or electric alternatives, the above figures must be considerably modified in order to arrive at a true comparison of the relative costs of equivalent heat production. There are, moreover, many different aspects from which alternative methods of heat production may be considered ; and since we are concerned not always mainly with the quantity of heat available, but more often rather with the production of comfortable conditions, it does not necessarily follow that computations based upon equal heat production will be indicative of actual needs. It is obvious, for instance, that neither gas not electricity shows to the best advantage for continuous heating, since for intermittent use the fact that either can be turned on or off at will results in a substantial reduction in the amount of heat required as compared with that necessary from a continuously burning coal or coke fire. Again, electric heaters are portable, and since they can be placed in any convenient position, they are often able to keep the occupants of a room comfortably warm by the emission of less radiant energy than would be required from a more distant coal fire, necessarily situated on the hearth. Since the use of solid fuel involves a great deal of work, both directly in the laying of

fires, carrying of coal, cleaning of grates and sweeping of chimneys, and indirectly through the effects of dirt, gas fires for periodic use aggregating only a few hours a day generally prove in practice decidedly cheaper than either coal or coke fires. And even electric heaters, by their convenience and adaptability, may sometimes repay for the higher cost of the units dissipated. Where energy can be obtained for less than 1d. per unit, electricity may be regarded as a serious rival of coal for intermittent heating. For continuous heating the cost of gas is very high, that of electricity quite prohibitive, in relation to the cost of solid fuel.

Gas cookers are convenient and easily controlled, and unexpected demands for hot food can be met with ease. The efficiency of the gas oven is greatly in excess of that of coal-heated ovens, and so appreciable is this advantage that, were the oven the sole consideration, gas would prove not only more desirable to use than coal, but actually cheaper as well. But due regard must be paid to the fact that while the gas consumed is being applied solely to cooking operations, the coal range is available for boiling pans, heating irons, producing a supply of hot water for domestic uses, etc. Where, however, such secondary services are not required, a gas cooker would probably prove more economical in use. The maintenance and running cost of electric cookers as a rule is higher than that of gas cookers, but in certain cases their installation might be justified. For water heating, electricity is much dearer than gas, and either much dearer than the independent coke fired boiler.

It may be gathered that for the production of heat, electricity, except in certain special cases may be regarded as a luxury, though its adoption for cooking purposes is likely to increase more rapidly. There has been for many years a rapid and continuous increase in the number of gas-heated appliances, and especially gas cookers of various kinds, loaned or hired or sold by the various companies ; but the total quantity of coal dealt with by the gas industry (16-18 million tons annually) is still far exceeded by that which is burned in its raw state in our domestic grates alone—(40 million tons annually)—and that notwithstanding the fact that very considerable quantities of gas are required for industrial purposes. There is little doubt, however, that in many households the replacement of the old-fashioned kitchener by a gas cooker and a small coke-fired boiler or open grate with back-boiler for hot water supply, would prove not only a convenience, but actually an economy. For such purposes, and for warming rooms which are occupied for only a few hours each day, coal gas will undoubtedly be increasingly adopted ; but its relatively high cost for water heating or for warming continuously occupied rooms prevent its exclusive adoption for all purposes, and the demand for a cheap solid fuel is likely to persist. The problem which confronts us is therefore the production of a satisfactory smokeless substitute for raw coal, which, used in conjunction with gas and electricity, will make feasible the elimination of the domestic smoke nuisance.

In view of these considerations, it is not surprising to find that of late much attention has been directed towards the possibilities of gas coke for household use. The total annual consumption of gas coke in this country approaches 7 million tons, but most of this is used for industrial purposes. With the housewife, gas coke is unpopular,

largely, no doubt, on account of the difficulty of ignition and relatively low combustibility. These drawbacks are to be attributed partly to the low volatile content of gas coke, and partly to its inherent physical characteristics ; but they are frequently accentuated by the presence of large amounts of moisture and ash, and by the practice of selling coke ungraded *i.e.*, not separated according to size. The result is, that while ordinary gas coke can be used without difficulty for central heating installations or for independent boilers, in open grates, coke fires, although they usually have a thermal advantage as compared with coal, are difficult to light, and difficult to maintain unless very big fires are kept up ; while in kitchen ranges they may fail to heat either oven or water boiler satisfactorily.

There is little doubt that of the large amount of coal used in this country for domestic purposes by far the greater proportion finds its way into the kitchen. But here coke unfortunately frequently fails to put up a creditable performance. The failure is not due solely to the nature of coke as a fuel, but also to the design and construction of many of our kitchen ranges, which allow of in-leakage of cold air to oven and boiler flues. The consequent chilling of the hot products of combustion may prevent coke from acting successfully, although, when coal is used the passage of flame around the flues may save the situation. Such a failure of coke, however, is an indication of the unnecessary extravagance with which coal is burned in such ranges. But with improved draught control and flue entrances placed low in relation to the fire bed, so that even when the mass of fuel in the grate has fallen low air cannot be drawn into them without previously passing through a layer of incandescent fuel, there is no reason why high grade coke should not be able to replace raw coal for all domestic purposes. On the other hand, furnace practice has shown the important function of radiation in the heat transfer from hot gases to solid surfaces, and since the radiation from luminous flames is greatly in excess of that from non-luminous hot gases, it will probably be necessary to reckon with the fact that heat transfer may be less rapid with coke than with coal as fuel. It might therefore be advisable so to modify the design of kitchen ranges as to take advantage of the high intensity of direct radiation from incandescent coke for oven heating purposes.

However this may be, the housewife generally cannot be expected to consider coke an attractive substitute for coal unless cleaner and more readily ignitible qualities can be offered to her. The shortcomings of ordinary coke as a domestic fuel and the improbability of gas or electricity in the immediate future wholly displacing solid fuels, together with a growing realisation of the seriousness of the smoke problem, have thus led to a readjustment of ideas on the subject of coal carbonisation. And simultaneously with the development of processes aiming at the complete gasification of coal, or at least at a substantial increase in the gas yield, investigations have been proceeding with a view to perfecting a method designed primarily for the production of a free-burning, smokeless coke, suitable for domestic and other purposes, and for the recovery as by-products of fuel oil, gas, oil and motor spirit as a possible home source of supplies both for the navy and mercantile marine. This process is based upon the carbonisation of coal at temperatures low in relation to those obtaining in normal gasworks practice,

and is therefore termed "low-temperature" carbonisation, other processes in contradistinction being referred to as high-temperature carbonisation. Its possibilities from the point of view of the manufacture of an easily combustible solid fuel have long been foreseen, but practical difficulties have barred the way to making the process a successful commercial venture.

Since the temperatures to which the coal is heated are reduced, the volatile constituents are less completely extracted, and the gas yield is consequently reduced to the equivalent of only some 10 to 12 per cent. of the heat value of the original coal. It is, however, a very rich gas, of calorific value 1,100 to 700 B. Th. U. per cubic foot, and has certain special applications. On the other hand, the residue of solid fuel, or coke, is relatively high, usually approximating to about 14 cwt. or a further 70 per cent. of the calorific value of the coal, and the additional proportion of gaseous matter which it contains as compared with ordinary gas coke helps it to light easily and improves its value as a domestic fuel. In addition to gas and coke, about 15 gallons of oil, equivalent to about 8 per cent. of the heat value of the original coal, can be recovered. When due allowance has been made for the fuel required for heating the retorts the overall thermal efficiency does not differ materially from that associated with high temperature processes.

The solid fuel produced by carbonisation at low temperature is particularly well suited to domestic requirements. As has already been pointed out, owing to the limitation of the temperatures to which the coal is heated in this method of treatment, the gaseous matter is less completely extracted from it, and a higher proportion is thus retained in the coke. This enhances its value as a fuel, but the corresponding reduction in the gas yield introduces economic difficulties. Since the price obtainable for heat units in gas is relatively very high it follows that if the yield of this product is diminished an extra burden must inevitably be thrown on the other products. It is thus doubtful whether low temperature cokes could be sold so cheaply as gas coke, especially as the overhead costs of the processes so far developed are relatively heavy. On the other hand, it is possible that the special nature of the gas and tars produced might enable them to command prices somewhat out of proportion to their thermal value, and so to free the solid product from the necessity for making good a deficit in the balance sheet. Surmise is of little profit in the solution of such a problem and as Dr. C. H. Lander has pointed out, until the products from full scale undertakings have been able to command in a free market the prices necessary to render enterprises commercially sound, taking account of depreciation and renewal of plant, the economic position of undertakings using low temperature methods must be regarded as uncertain and to a large degree speculative in character.

Pending the proving of the low temperature process, however, it would seem that the existing high temperature carbonisation industries are to be looked to as the most hopeful source of more immediate supplies of solid smokeless fuels. Dr. E. W. Smith has stated that while gas undertakings vary in the care they have taken in coke production, those companies which pay due regard to supplying their customers with a dry, graded coke, usually have little trouble in disposing of their products ; and that

although gasworks coke may not be an ideal smokeless fuel, yet its uses are rapidly extending. Dr. Smith's experience leads him to the view that if solid smokeless fuel is to meet with success in the domestic market it must (1) be sold on a competitive basis with house coal, (2) be combustible and easily ignitible, and (3) not cause the user extra trouble with ash or smell.

It is now well known that the combustibility of a coke is not determined solely by its volatile content or chemical nature, but is closely associated with its physical structure also. And it has been shown that by the proper blending of different types of coal prior to carbonisation, cokes of relatively high combustibility can be produced, even by high temperature processes. Much work still remains to be done before successful results can safely be anticipated in all cases and the whole subject is yet in a state of some uncertainty. Modifications of methods in full scale installations are bound to be gradual, but the simultaneous production of a high gas yield and coke of improved quality should offer an attractive prospect to the industry. Further, since a steady market for coke should react favourably upon the price of gas, increase in the demand for one might be expected to induce an accompanying increase in the demand for the the other, and thus to accelerate the displacement of raw coal.

The ash content of a coke depends largely upon the amount of ash in the coal from which it is prepared, but there are methods whereby most of this can be got rid of prior to carbonisation, and a coke low in ash consequently produced. Such coal cleaning processes are attracting a good deal of attention at the present time, especially those which have for their object the dry cleaning of coal, but their development will be governed by economic considerations.

The large amount of water usually associated with coke is due to the practice of "quenching" it, or in other words, of cooling it upon its discharge from the retorts by directing upon it water from a hose pipe. Where carbonisation is carried out in continuous vertical retorts, the coke can be cooled by the injection of steam at the base of the retorts, and in consequence retains very little water. Processes are available for the "dry quenching" of coke from other types of installation, for example, by passing over it a stream of inert gas, the heat absorbed by which can subsequently be utilised for steam generation ; but the economic success of such methods depends upon local conditions, and their adoption may in some cases be considered impracticable. But even where coke is cooled by water, if the quantity used is strictly limited it need not retain more than a few per cent.

Dr. C. H. Lander has summarised briefly the requirements of a solid smokeless fuel as follows :—

1. *Pre-Treatment to render Smokeless.*—It must have been previously treated for the recovery of valuable by-products from raw coal and so rendered smokeless.
2. *Ease of Ignition and Combustion.*—It must either contain sufficient volatile matter, say 7 to 10 per cent. or be of such a structure as to be easily kindled and kept alight in open fireplaces as at present constructed.

3. *Low Ash Content.*—It must have a relatively low ash content, partly to prevent an undue reduction in its calorific value, and partly to reduce the dust resultant upon combustion in household fires.
4. *Strength.*—It must not be so friable as to break easily during handling and transport.
5. *Compactness.*—It must be compact, but not of such a structure that the ash formed during combustion covers the surface of the fuel in such a manner as to hinder combustion.
6. *Price.*—Its price must be sufficiently low, so that when other advantages are taken into account it will attract purchasers away from bituminous coal.
7. *Low Moisture Content.*—It must be low in moisture to prevent a large amount of the heat in the fuel being used in driving off the moisture, and to avoid a loss in radiating efficiency.
8. *Grading.*—It must be suitably graded for the purpose to which it is to be put.

Whatever the path by which the desired goal may be reached, there unquestionably exists an urgent and very real necessity for preventing the waste of by-products which the present custom of burning raw coal involves, and for substituting some form, or forms, of smokeless fuel. Different methods of pre-treatment are suited to different classes of coals, and the proper allocation of our coal supplies is therefore a matter of great importance. The demands of the gas industry are in general for a high grade coking coal giving a maximum gas yield, though of late the advantages of blending coals, both for improvement of the resultant coke, and for increasing the throughpnt in vertical retorts, have become more apparent. On the other hand, power stations are able to make use of inferior coals, while the low temperature process is also applicable to a wide range of coals by means of suitable treatment.

It is very important to develop means for utilising all existing types of coals. For instance, it is well known that millions of tons of low grade slack is left behind in the mines on account of its low commercial value ; but this, suitably dealt with, could be devoted to useful purposes. On the other hand, coals which would be eminently suitable for gas manufacture frequently are disposed of for purposes to which their special properties are not essential. And so on. The desirability of purchasing coals to specification, therefore, is apparent, and the general adoption of such a method, although very difficult to put successfully into practice, would mark a very definite step forward.

As was pointed out in the Report of the Royal Commision on the Coal Industry (1925) the question, which of the many possible methods, or combinations of methods, of using coal should be adopted in any given case depends upon a variety of factors, the principal of which were summarised as follows :—

(*a*) The composition of the coals that are available and their comparative prices.
(*b*) The possibility of using small or waste coal.
(*c*) The markets that are available for the energy or the by-products and the prices to be obtained.
(*d*) The capital costs of the alternative plants.

(*e*) The labour costs of the processes.

(*f*) For the generation of electricity, the existence of adequate water-supplies for cooling.

Future methods of fuel treatment are thus likely to remain very diverse and existing methods will no doubt continue to develop side by side with such innovations as may prove to be workable upon a sound commercial basis. We may confidently expect a steady increase in the amount of usefully applied energy obtainable from a given consumption of coal together with a gradual reduction in the emission of smoke and noxious vapours ; and it is the aim of all workers in this field to accelerate progress in these directions.

DISCUSSION.

Mr. Roberts (Manchester) said that he would like to ask Dr. Fishenden whether she had conducted any experiments with regard to grates which consumed both the coke, low temperature fuels and coal, and if so, could she give the meeting the results of these tests, especially with reference to the semi-well grates, referred to by the Chairman. He would be interested to know whether she had found that coal, coke, or low temperature fuels burned well in the "well," or bar-less grates. He was of the opinion that one explanation of the fact that there had been less smoke from domestic chimneys during the last few years, was that greater care had been taken in the construction of flues. In days past tremendous spaces were left above the grates. As an instance of this, a great amount of money was spent on Dalton Hall, near Manchester, where great discomfort was occasioned by the way the chimneys smoked. It was found that this had been due to the tremendous spaces left above the grates. It was remedied by reducing the flues as mush as possible and allowing as small a quantity of air to get at the fuel as possible. He took it that Dr. Fishenden had not found coke a success for use in the kitchen range, as she had said that the only really successful fuel for ranges and for cooking at present was coal, and it was undoubtedly cheaper than any other fuel.

Dr. J. W. Graham asked whether Dr. Fishenden could give them an opinion on the Maclaurin process which they had heard of from Glasgow. If their Glasgow friends had solved the problem of low temperature carbonisation, they would be glad to know something of it. He wondered if Dr. Fishenden could enlighten them.

The Chairman, interposing, said that he thought the question rather premature, and it would be better for them to await the official report.

Dr. Owens said that some reference had been made to the American coal strike two years ago, and he thought it would interest the conference to know that during the strike he received reports from the U.S. Weather Bureau as to the amount of atmospheric pollution which could be traced to the strike of anthracite miners. The smoke trouble during that time rose tremendously, owing to the fact that soft coals had to be used for industrial purposes, and attention was continually drawn in the letters from the bureau to this fact.

Dr. Fishenden had referred to the possibility of using cheap coal for generating electricity. He thought there was one thing we were liable to forget in this connection. That was the necessary magnitude of any scheme which might ultimately be adopted as a smokeless source of heat. It sounded all right to use ordinary cheap coal, such as colliery waste for the purpose indicated, but there would not be enough cheap coal to provide us with all the heat we should require. Where was the cheap coal coming from in sufficient quantities ? It would be no use doing the thing on a small scale if it would not ultimately lead to a solution, *i.e.*, provide a substitute for the forty million tons of coal used annually for domestic purposes.

With regard to the question of domestic heating, he was inclined to think that there was too great a tendency to talk about the efficiency of radiation. They regarded the domestic heating apparatus as purely a device for emitting heat, and were inclined to lose sight of the fact that in this country the heating of our houses had been unconsciously combined with the ventilation. In considering any new method of heating, therefore, this point should be kept in mind. Heating by electricity was all right, but what about the ventilation ? You did not get any—and that was a point that had been forgotten by many. He asked them to consider the function of a domestic fire. It was not to give out heat alone. It was to make the inhabitants of the house comfortable. One had to keep the house dry. It had been said that in most cases only 20 per cent. efficiency was got from an average fire in an average room in a dwelling house. But the low efficiency did not denote all loss. True, there was loss in what went out of the chimney, but the house was being dried and ventilated, and the fire was functioning in many other directions they were not aware of. The use of that word *efficiency* was hopelessly misunderstood. They must remember that it was not a question of heat alone—but comfort.

Another point occurred to him : There had been a great deal of talk about the development of a smokeless fuel. He wanted them for a moment to picture their ancestors when they dug up a little coal and found that it would burn. They burned it in a hole in the floors of their huts, but they also found that in the process they smothered themselves and their huts with the smoke. They gradually developed from that time until they found a method of burning this new-found fuel. They discovered a method and we still had it, and having it, we were now trying to force this same method or process to burn every other kind of fuel. It was surely not logical. There was another way of approaching the whole problem. We now had certain smokeless fuels such as coke. Why not approach the problem in the manner of our ancestors by trying to find the suitable method of burning them. In other words, adopt the apparatus to the fuel, instead of the fuel to the apparatus.

Mr. Munro (Glasgow) said that in Glasgow an important experiment, which had been hitherto a secret, was being carried out, by which the electric current would be generated by a direct connection with a gas turbine. He was confident that they were going to get gas direct from coal and generate the electricity from the gas turbine.

The Corporation had made a contract with a local colliery firm six miles out of

the city, and they were taking a million cubic feet of gas a day and were paying 10d. per thousand cubic feet. If the big coke owners of this country would only set up these plants it would be possible for the cities to get their gas direct from the coke ovens.

Another point of interest was that in Glasgow they now purchased their coal to a specification. They stipulated for a certain thermal value in the coal they bought, and had been able to get a clause in every coal contract to the effect that there must not be more than 10 per cent. of ash in the coal they used for the municipal undertakings. With regard to the smokeless fuel experiments which they carried out in Glasgow, he had to confess that during the first six months they were not a success, but they terminated successfully last October, and they were now selling on the streets of the city their "Kincole" at 2/- per cwt. to the people. They sold it to the hawkers for 30/- a ton in bags. Average coal in Glasgow, before the strike, was sold at 42/- a ton. They were now selling smokeless fuel to the people at 2/- less per ton than good coal cost before the strike.

In Glasgow they had also discovered some very valuable by-products, including a new non-poisonous green dye which was going to be used by a large wallpaper firm. This firm had agreed to take all that they could produce, and it was going to replace the poisonous substance hitherto used in the manufacture of green wallpapers. There was no doubt that in rooms where wallpaper containing the posionous arsenious oxides had been used, the inhabitants were continually breathing the poison. They had discovered other very valuable by-products which had remained undiscovered in the high carbonisation process. They had discovered by experiment that any coal with a coking index from 16 was good enough for the making of the smokeless fuel.

Dr. DUNN (Newcastle) said he would like to pay a tribute to Dr. Fishenden for her paper. He had had a considerable personal experience of the burning of smokeless fuels and coke in ordinary grates since 1913, and while it was quite practicable to burn ordinary coal-gas coke in many ordinary grates, he had not come across any sample of coke to be compared with the low temperature cokes for domestic consumption in grates and ranges of all descriptions. He thought they might look forward with very great interest to the time when Maclaurin's or some of the other processes would have developed so far as to yield a commercially available smokeless coke. While he had found it very difficult to convert either his wife or his cook to coke as a household fuel, both were converted by the advantages offered by the low temperature coke, and were very sorry when the temporarily available supply came to an end. He felt confident that when low temperature coke did become generally available it would be widely adopted. It was not available yet, and they had to do the best they could with ordinary coke. A very desirable thing—in fact, an essential—was to have a coke with a low ash. In Newcastle they had not only the gas companies to supply them with coke, but close to the city was a very large firm which made foundry and blast-furnace coke. This coke was all graded, and the "Nuts" were sold for household combustion. Though, because of the high temperature of its formation, one might have expected that this coke would be more difficult to burn than ordinary gas coke, yet in fact (no doubt largely

because it was made from washed coal, and contained much less ash on the average than gas coke) it proved to be more suitable than gas-coke for use in domestic grates. He would like to remind the meeting that in comparing coke with coal for household purposes, they must bear in mind that the great bulk of the coal burned in household grates was a picked coal containing very little ash—frequently as low as three or four per cent.—and that coke made from a coal with such a low ash would be preferable as a fuel to any of the coke now upon the market.

But he did consider, from the results of his experiments, that it was a very practicable thing to burn coke quite satisfactorily in the household grates of the ordinary type, if householders and their wives would only feel their responsibility in the matter of smoke abatement and set out really to endeavour to burn coke in their grates.

The disadvantages of coke in heating ovens lay not so much in the coke itself as in the construction of ovens. The hot, unburnt gases coming from coal in the grate meet in the flues of the oven with the air they need for their combustion, burn on the spot, and generate in the flues themselves the heat needed for the oven. The hot gases from coke are completely burnt and can only give us to the oven their sensible heat: when they are diluted and cooled by air entering through leaks in the flues, they can no longer raise the oven to the necessary temperature.

If ovens were properly constructed without leaks in the flues, and the grate so arranged that no excess air could reach the flue, no difficulty would be experienced in using coke for oven-heating. In fact it would be found as satisfactory as coal.

Dr. Smith said that he thought it would be well if those interested in smoke abatement would thoroughly examine the fire grate patented by Dr. Owen—about which he had "kept things so dark"—and which was on show in the exhibition. The principle of this grate was the finest, to his mind, that had yet been brought out. If they could only induce their gas companies to supply these to tenants on the permanent hire system, as they did the gas fires and stoves, it would be an immediate tremendous advance. However, Dr. Owen must not be taken, in his remarks on the advantages of coal, to mean that he was in favour of perpetuating the use of coal for domestic purposes. He merely wanted them to look at points on the other side of the question which had to be taken into account.

It would be very useful to learn from the Glasgow representatives what efficiency was claimed for the new turbine mentioned by Mr. Munro. From information he had received he would be inclined to say that the word "turbine" was misapplied to the new apparatus. Though an excellent machine, no doubt, he felt that it could not be a turbine. Its efficiency had not been indicated. Furthermore, with regard to the purchasing of gas at 10d. a thousand cubic feet from Nimmo's by the Glasgow Corporation, he would like to point out that 10d. a thousand on impure gas was not reducing the price very materially. What they had to go out for were still cheaper methods of producing gas either at the coke-ovens or at the gas works. Both the gas and the coke must be produced at the gas works to get them at the lowest cost which, by the way, was the only way to enable the average housewife to afford these new fuels.

Dr. FISHENDEN, replying to Mr. Roberts, said that the results of a series of tests carried out by her department had been published in Technical Paper No. 13, under the title of "The Design of Grates." A comprehensive series of tests of coke in different types of sitting-room grates and kitchen ranges was about to be embarked upon. As Dr. Dunn had pointed out, the kitchen range presented the more important problem, since it consumed the greater proportion of the coal used for domestic purposes. The failure of coke in kitchen ranges seemed to her to indicate how inefficiently coal must be used in them. She thought that if people could be persuaded to give a high-grade gas-coke a fair trial, many of them would continue to use it permanently. She could not discuss the probable future of the Maclaurin process. The results must be waited for, but many different types of coal were available in this country, and there was room for different types of treatment. She did not agree with Dr. Owens that electricity alone was to be looked to as a substitute for coal. Electricity would take its place among smokeless fuels. The outlook for any given form of energy depended upon the conditions, and what might prove a practical proposition in one case might be out of the question in another.

She had been interested in Dr. Dunn's remarks about low temperature coke. There were some who contended that the amount of volatile matter remaining in a coke had nothing to do with its ignitability and combustibility, but her experience suggested, as, indeed would be anticipated, that a fairly high proportion of volatiles was an aid to lighting. Recent work seemed to show that ash was an important factor in the behaviour of cokes, and this aspect of the problem was likely to receive further attention. Her own experience was that ordinary gas coke, if of good quality, low in moisture and ash content, though not ideal, could be used in many cases, and was more convenient than coal. If there was to be any very rapid amelioration of the smoke nuisance, it would probably be partly through the use of coke.

Dr. SMITH then called on Mr. ACKERMANN to read his paper.

The Engineering Aspect of the Smokeless Production of Power

B6

By A. S. E. ACKERMANN, B.Sc. (Engineering), F.C.G.I., A.M.I.C.E.

INTRODUCTION.

When I was invited by Mr. Elliott, the energetic Honorary Secretary of the Smoke Abatement League of Great Britain, to prepare some notes on the Engineering Aspect of the Smokeless Production of Power for the purpose of causing a discussion of the subject, he was careful to tell me not to go into much detail, but to deal with the matter in a general way. This was well, for though keeping more or less to generalities, it has been difficult so to reduce the available matter that it may be read to you in about

forty minutes. The notes are somewhat disjointed and incomplete, but will, I hope, serve the purpose in view.

The following are some of the principal factors in the smokeless production of power :—

(1) There must be ample boiler and combustion chamber capacity.

(2) Efficient stoking, whether mechanical or by hand. To encourage this, a bonus may be given for the absence of smoke with a high percentage of CO_2.

(3) Pre-heating of the air supply to the furnaces by means of some of the heat in the flue-gases which otherwise would become a chimney loss.

(4) Thermal storage where the load is variable, for it is very difficult to avoid smoke when the demand for steam varies from hour to hour.

(5) Powdered fuel (which is coming in rapidly, and is already largely used in America) is certainly an aid to economy and absence of smoke, and it facilitates dealing with a fluctuating demand for steam. It is invariably used in this country for cement making furnaces. In America they are controlling the supply of pulverised fuel and air, by the variation of the demand for steam, as made manifest by the rate of flow of the steam in the main. Thus the human element is eliminated. A great advantage of pulverised fuel is that much less excess of air is required, say 25 per cent. instead of about 50 per cent. in the case of mechanical stoking. By excess air is meant the quantity in excess of that which is necessary from a purely chemical point of view for converting the carbon into CO_2 and the hydrogen into water.

Dr. J. T. Dunn made some experiments which showed that only 12 to 15 per cent. of the ash of powdered coal could have gone up the stack, and other tests have failed to detect any ash deposited from chimneys where powdered fuel was used, although it was detected in the case of installations using other methods of burning solid fuel. Besides, such ash is a very innocuous material compared with the tar and soot of smoke. I was engaged in a case where it was alleged that the dust from several 150 foot chimneys was making it necessary for a grocer to keep his bacon covered. Gritty bacon may not be pleasant to eat, but the covering of the bacon kept flies off, and they, as is well-known, are the conveyors of much infection, so the action of the alleged dust was really beneficial in the end! These were, however, not the chimneys of a pulverised fuel plant, but of a large steel works.

To give a rough idea of the cost, it may be said that pulverising coal adds about 2 per cent. to its cost (which is low because very inferior coal may be used) and causes it to yield about 5 per cent. more steam.

Instead of firing with powdered coal in the state that it leaves the pulverisers, in the McEwan-Runge system the fine particles of coal are turned into semi-coke by being allowed to fall through one or more, often two, vertical retorts, each 30 feet high. These are not heated externally, but

there is an upward current of hot inert gases. The mean temperature in the upper retort is 600°F., this being sufficient to prevent the particles of coal from cohering. The mean temperature in the lower retort is about 1,000°F., which completes the process of converting the fine particles of coal into small particles of semi-coke. Smoky gas is, of course, given off during the process. About one-third of this gas is used for working the plant, the other two-thirds being available for any desired purpose. One advantage of the process is that the fine semi-coke may be stored without danger or deterioration. A second advantage, from the point of view we have in mind, is that even its unskilful use, in place of powdered coal cannot cause it to produce smoke.

(6) Producer gas is used on a large scale for steel furnaces, and I have tested boiler plants fired with crude producer gas which showed an efficiency considerably above the average.

The Wollaston Gas Producer Boiler consists of a vertical gas-producer or a more or less ordinary type, but having for its upper part the fire-box of a Cochran vertical boiler. A published test of one of these boilers gives the efficiency of the producer as 88 per cent. and the all-round efficiency as 73.8 per cent.

Messrs. Spencer Bonecourt, Ltd., have supplied me with particulars of their town-gas-fired boilers. From these it is found that even so small a boiler as one having an evaporation of 397 pounds from and at 212°F. per hour, has a thermal efficiency of 86 per cent., while one having an evaporation from and at 212°F. of 11,500 pounds per hour, and without an economiser, had an efficiency of 90 per cent. These boilers are fitted with horizontal fire tubes, and each tube is provided with a large Bunsen burner.

A particular interesting boiler is that invented and designed by Messrs. Brunler, father and son. It is well-known that in heat transmission, the chief resistance occurs at the surface separating two media, *e.g.*, the heat from the hot gases in a fire-box experiences this resistance at the surface of the metal forming the fire-box. The passage through the metal is comparatively easy. Then there is again the increased resistance at the surface separating the metal from the water in the boiler. Messrs. Brunler have eliminated one of these two surfaces of separation, for they have an oil burner, the flame of which burns *in the water inside the boiler*. Consequently, the pressure of the oil and the air for its combustion have to be above that of the steam in the boiler.

(7) Oil fuel is, of course, excellent, and is much used for glass furnaces, as well as steam making. But it is expensive. Like anything else, if improperly used, it can make a particular black smoke.

(8) In America large quantities of natural gas are used. We, unfortunately, are not favoured by a supply of natural gas, but we are using blast-furnace gas.

(9) Great improvements could be made in the method of lighting locomotive fires. Some time ago I was professionally engaged in the action brought by

the late Sir Herbert Leon, Bart., against the L.M.S. Railway for damage done to his property at Bletchley Park by smoke from locomotives, the fires of which were lighted on a siding adjoining the plaintiff's property. After a hearing of ten days the defendants settled the case and paid the plaintiff's taxed costs. In America, large oil-burners (like a gigantic blow-lamp) are used for lighting locomotive fires. This greatly reduces the production of smoke. The celebrated Rainhill trials of locomotives were run on coke, and for many years no other fuel was used for locomotives.

(10) The use of hydraulic and electric power, and the distribution of producer gas (as is done by the South Staffordshire Mond Gas Co.) are all means which result in a higher efficiency and less smoke.

Dr. J. S. Owens recently estimated that the cost arising either directly or indirectly from smoke was in the case of London about £8,000,000 per annum, a sum it would be well worth saving even in these days of high expenditure. Taking Great Britain as a whole, we may say the cost is about £40,000,000 per annum. This, surely, apart from the questions of health and cheerfulness and a feeling of general well-being, is a sum well worth saving, for the damage really is done, though it is spread over such a wide area, is so insiduous, and, unfortunately, we are so accustomed to it, that, like eels and skinning, we are used to it.

The Coal Commission (Report, 1926, Pt. 1, p. 24) states "the work of over a million men for three days every year is devoted to providing the soot which pollutes our atmosphere."

COST OF SMOKE PREVENTION.

Complaint is often made that it it costly to avoid smoke production, consequently, on May 28th, 1914, the Coal Smoke Abatement Society sent a questionaire to 389 firms in the L.C.C. area. Each of these firms had in previous years been an offender as regards smoke production, but, during the twelve months immediately preceding May 28th, 1914, none of them had been reported to the C.S.A. Society in respect of smoke nuisance. One hundred and sixty-three of these firms replied, which was an excellent response considering the circumstances.

Question No. 3 was

> "Have your efforts to secure smoke abatement led directly or indirectly to economy in fuel or in the general cost of working, or both ?"

To this question 99 firms replied as follows :—

56 reported that economy had resulted.
28 reported that there had been a greater expense.
10 stated that no data were available.
5 sundry answers.
—
99

It is pleasing that over 50 per cent. experienced a positive and measurable economy.

Mr. Lawrence Chubb, the Secretary of the Coal Smoke Abatement Society, gave evidence before the Departmental Committee of the Local Government Board on Smoke Abatement in June, 1914, and in reference to economy said :—

> "It has, for instance, been stated on behalf of Messrs. Crosfields, of Warrington, that the installation of modern appliances and the adoption of modern methods have led to a saving of over 1,000 tons of coal per week. The saving in this and other directions has been computed to amount to at least £25,000 per annum (*vide* Dr. Ormandy's statement, p. 109 of 1905 Conference papers).
>
> "Again, the Chief Engineer of the Central London Railway has publicly stated that the methods he has adopted at Shepherd's Bush have not only got rid of the smoke nuisance, but have resulted in a saving of 500 tons of coal per week. They now burn 600 tons of coal instead of 1,100 as hitherto. In this case, automatic CO_2 recorders are used, a system of regular boiler testing and training of fireman has been adopted, and the stokers are paid a bonus of from 4/- to 5/- per week upon the results obtained."

Before giving a few particulars of some of the latest and largest power plants, I wish to remind you that an ideal boiler plant is shown by a full-sized exhibit in connection with this congress. It is hoped that it will do much to improve such cases as those just referred to, and that the exhibitors will be repaid for their enterprise in forming the exhibit. All who are interested in the efficient production of steam should carefully examine this model plant, not "model" in the sense of small, but in the sense of ideal, *i.e.*, what is the best that present day engineers can do in this matter.

EFFICIENCY OF STEAM BOILERS.

As to the efficiency of steam boilers, in my young days, 70 per cent. was considered a good result ; now, 90 per cent. has been claimed for a patent gas-fired boiler, and 90 per cent. is perhaps possible with pulverised coal. In fact, it is stated that the Hell Gate Power Station, of New York City, has given nearly 93 per cent. boiler efficiency with mechanical stoking and the walls of the combustion chamber lined with 4 inch water tubes. Pulverised fuel should give a small increase even on this. Obviously, there is not much possibility of smoke production with an efficiency of 93 per cent., for the total losses due to the temperature of the flue gases, radiation, and smoke is then only 7 per cent. On the other hand, in this country the average efficiency of a great number of boilers is under 60 per cent., an appreciable amount of the lost 40 per cent. being due to unconsumed carbon in the form of smoke.

SOME MODERN POWER STATIONS.

The Langerbrugge Power Station, near Ghent, Belgium, has three water-tube boilers with a joint capacity of 72,200 pounds of steam per hour. This is not much for a modern power station, but the novelty of this station is that its steam pressure is 800

pounds per square inch and that the steam is superheated to a temperature of 842°F. The air supply to the furnaces is pre-heated by means of the flue gases to 360°F. The firing is with coal on chain grates. Subsidiary burners are fitted at the back of the furnaces for using either oil or colloidal fuel (powdered coal mixed with 50 per cent. of fuel oil). These are for use in case of the chain-grates failing, and for dealing with peak loads. Both forced and induced draught are used.

Artesian well water is used in the evaporators, so that the feed is pure distilled water which cannot form scale. This would be exceptionally dangerous with such temperatures and pressures. Corrosion is eliminated by entirely enclosing the feed system, so that there cannot be any absorption by the feed water of deleterious gases. Live steam feed water heaters raise the temperature of the feed to 384°F.

Early this year, Messrs. Yarrow & Co. installed two water tube boilers at Paisley for Messrs. J. & P. Coates, which are oil-fired. The steam pressure in this case is only 258 pounds per square inch. The official trial at normal load proved the actual evaporation per hour to be over 40,000 pounds with a feed temperature of only 102°F. The actual evaporation per pound of oil was 11.9 pound, and the thermal efficiency was the excellent one of 83.8 per cent., the guaranteed efficiency being 81 per cent.

Most boilers for the use of powdered fuel have enormous fire-boxes. That so large a fire-box is not necessary is proved by the excellent results obtained at the Dover Corporation Electricity Works, where a Vicker-Spearing water tube boiler of 30,000 pounds per hour capacity has been fitted by the Lindley Duffield Co. with a novel form of fire-box, consisting of two fire-brick basins. Each of these is 8 feet high, and has a major diameter of 9 feet and a minor diameter of 7 feet 6 inches. The coal dust and air enter these tangentially and the flame forms a vortex in the basin. Owing to the temperature, and the centrifugal action of the swirling flame, the particles of ash are fused into slag, and this coats the fire-bricks and thus protects them from the highest temperature. The slag gradually trickles down to the bottom of the basin and is allowed to escape from there. It is said to be totally unlike that usually produced, being more like pumice stone. When it is mentioned that the height measured on the vertical axes of the basins from their rims to the underside of the water tubes is only 4 feet 6 inches, it will be realised how very much smaller this fire-box is than the American type. The results obtained with this boiler are also most satisfactory, namely, a thermal efficiency of 83 per cent. using Kent coal, having a heat value of 11,450 b.t.u. per pound and containing no less than 15.4 per cent. of ash. The evaporation was 11.8 pounds of steam per 1 pound of fuel.

The Engineer (p. 320, March 19th, 1926) said that the chimney was emitting no real smoke, and expressed the opinion that when the dust catcher had been fixed "the chimney will cause no nuisance, a matter of considerable importance as the plant is situated among residential quarters in a natural hollow."

The Barking Power Station, of the County of London Electric Supply Co., Ltd., was opened in May, 1925. Only half of one section (of which there are to be six) is at present completed, and this consists of twelve water tube boilers, fitted with chain

grates, using pre-heated air, each having a normal capacity of 68,000 pounds of steam per hour. The second half of this unit will have the same capacity, but the fuel will be powdered coal.

Another method of power-production is that which has been tried on a large scale by the Butterley Co. (in conjunction with Midland Coal Products Ltd.) and by the Staveley Coal & Iron Co. In these a low temperature carbonisation process is used in conjunction with gas engines. The Staveley Co. use an externally heated cast-iron retort for the carbonisation. Its temperature is about 930°F., the contents are continually stirred, and further to facilitate the giving off of the gas, the retort is worked under a high vacuum. Mr. Chas. Markam, the engineer of the Staveley Co., has also designed a process which employs an intermittent, vertical, internally heated retort, in which the charge is first lighted at the top, and a carefully regulated supply of air and steam is passed in at this point and drawn down through the charge. The fire travels gradually to the bottom, driving off all the gases in front of it. Heated inert gases and the exhaust from a 7,150 h.p. Cockerill gas engine are used in connection with this retort. The gas engine is run on blast furnace gas which, after cleaning, contains .02 gram. of dust and 18 grams. of water per cubic metre. The mechanical efficiency of this engine is 85 per cent. The volume of the exhaust gases is the huge amount of 3,500,000 cubic feet per hour, with a mean temperature of 1,110°F. This exhaust is passed through two Cockerill waste heat boilers provided with superheaters and feed water heaters. Each of these boilers yields 7,050 pounds of steam at 200 pounds per square inch, and a superheated temperature of 570°F.

One ingenious method of reducing the size of a powdered-fuel boiler is that devised by Mr. W. R. Wood, senior vice-president, International Combustion Engineering Corporation, and made by Messrs. Combustion Steam Generator Ltd., who have a boiler which can be fired only with powdered fuel or oil, a great consideration from the point of view of this conference. It is a water tube boiler of which there is practically nothing except the combustion changer. In other words, the rectangular fire-box is lined with boiler-tubes of the fin type. Four burners are placed at the four corners near the top, and are so directed as to cause a vortex of flame which descends towards a multitubular water-screen. The gases and ash pass through this into a chamber where the ash is deposited. The hot gases pass on to a superheater and then to the air pre-heater. One of these boilers has been in use for some time at the steel works of Messrs. Taylor Bros. When evaporating at the rate of 70,000 pounds of steam per hour it is stated to have an efficiency of 88 per cent., largely due to the fact that it utilises all the *radiant* heat of the fuel.

MERCURY VAPOUR BOILER.

Dr. W. Le Roy Emmet has carried out some large scale experiments with the plant designed by him which primarily uses mercury in place of water. The word "primarily" is used, because after the mercury vapour is passed through a turbine, it is used to produce ordinary steam. The exhaust mercury also heats the mercury feed

to the mercury boiler. Such a plant having an output of 1,800 k.w. has been installed by the Hartford (Conn.) Electric Light Co. at Dutch Point. The heat is supplied by oil burners and the mercury vapour pressure is only 35 pounds per square inch, but its corresponding temperature is 812°F. The steam pressure of this plant is 200 pounds per square inch, and the steam has 100°F. of superheat. A surface condenser is used for condensing the mercury vapour. It is claimed for this system that where a good steam plant can supply one k.w. hour by the use of 18,250 B.t.u., only 12,300 B.t.u. (say 33 per cent. less) would be required in the case of a mercury vapour plant.

WATER POWER.

It is probably a popular fallacy to think that there is very little water power available in Great Britain, for, in fact, the amount is probably not less than 500,000 h.p. This may not seem much in these days when so many things are dealt with in millions, and even single water turbines develop 70,000 h.p. But let us consider what 500,000 h.p. represents in coal, for that is our present consideration, as the more power produced without the use of coal, the less chance there is of smoke production. Even with present day large units and high efficiencies, few steam plants give a b.h.p. hour for less than 2 pounds of coal. (The average for all England is probably 5 pounds or more per b.h.p. hour). We will assume 300 days of 12 working hours. Hence, 500,000 h.p. would need

$$\frac{300 \times 12 \times 500{,}000 \times 2}{2{,}240} = 1{,}607{,}000 \text{ tons of coal,}$$

and the cost of this would not be less than £1 per ton, *i.e.*, a saving on coal of over £1,500,000 sterling per annum. It must be remembered that quite low falls can be utilised by means of modern turbines, which would have been perfectly useless for the old-fashioned, though picturesque, overshot waterwheel. For example, at Strencham Mills, near Worcester, there is a Jonval turbine working under a varying head of water, giving 40 h.p. under a minimum head of only *two* feet. Even the maximum head in this case is only 4 feet 3 inches.

Efficiencies of 80 per cent. may be obtained with comparatively low fall water turbines. Going to the other extreme, the installation at Arniberg, on the St. Gothard Railway, has several units of 3,000 h.p. each, using a head of 2,800 feet, and at Fully, in the Canton of Valais, Switzerland, a head of 5,000 feet is being used by means of Pelton wheels running at 500 r.p.m. Each gives 3,000 b.h.p., and has an efficiency of 78 per cent. The largest water turbines are those at Niagara Falls, each of which has an output of 70,000 b.h.p. with a head of 160 feet.

My friend, Mr. Alphons Steiger, M.Inst.C.E., who has specialised in water turbines all his life, tells me that the water power in this country is used in a very wasteful way, and that if all the existing water wheels were replaced by turbines, more than double the power could be obtained. Evidently we are as wasteful of water as of coal.

The Lochaber (Scotland) water power scheme, now being carried out, includes the construction of a tunnel 15 miles long and 15 feet in diameter.

That we especially have need to conserve our coal resources is seen from the following data given by Mr. A. E. A. Edwards, M.I.Mech.E., to the Wolverhampton Engineering Society in December, 1919 :—

The United States of America	has	52%	of the known coal of the World
Canada	,,	16%	,, ,,
China	,,	13%	,, ,,
Germany	,,	6%	,, ,,
Great Britain	,,	$2\frac{1}{2}$%	,, ,,

The German share is lower now that France has recovered Alsace-Lorraine with its valuable coal deposits.

OTHER SOURCES OF ENERGY.

Besides the sources of energy already mentioned, there are at least the following : Wind, waves, tides, volcanic heat, primary electric batteries, alcohol, and some would have us include even chalk. The most elementary knowledge of chemistry tells us that chalk is calcium carbonate, which is a compound that has absorbed all the oxygen it can, and we might as well try to obtain heat by burning pure ash as by burning chalk. All these sources of energy are fortunately smokeless. Primary electric batteries usually obtain their energy from zinc, and such use of zinc may be considered as a slow and low temperature of "burning" of zinc. It is interesting to call in mind that zinc may also be burnt rapidly, and at a high temperature, much in the same way that coal is burnt. Coal does not ignite, *i.e.*, its carbon does not unite with the oxygen of the air until its temperature is a certain degree, corresponding with the flash point of oil. But this rapid burning of zinc is far less efficient for the purpose of power production that is its slow burning, whereby it is directly converted into electric energy. The reason for this is that if we were to burn zinc as a fuel, it would still mean the use of steam boilers and engines, and it is the combination of these which unfortunately and inherently causes a thermal loss of about 80 per cent. These facts suggest that there may some day be discovered a method of slowly "burning" coal at a low temperature in some sort of electric cell, and thereby converting its energy directly into electric energy. This would be a tremendous advantage, for not only would it be far more efficient (thus conserving coal) but it would also be entirely smokeless.

There is one more source of power which interests me personally, viz., sun-power, because for four years just before the war I was engaged professionally on this subject, and carried out about 40 complete tests of the two largest sun-plants that have been constructed. One was erected at Tacony, a suburb of Philadelphia, America, and the other was at Meadi, near Cairo, Egypt. The latter plant occupied nearly an acre and produced enough steam to supply 65 b.h.p. for eight or nine hours a day. Such a plant would be useless for about 360 days per annum in Great Britain, but there are places in the Empire, in Egypt, America, and even in Europe where such plants would work well. It is merely a question of prime cost, interest on capital, and depreciation. The early forms of almost any new thing are less efficient and more

costly than the later, but it is almost certain that the vast supply of solar energy will be used in the future.

The more electricity is used for power purposes the less smoke there will be, not, of course, as some think, that electricity is as a rule produced in some mysterious way without the use of coal, but because when produced in bulk the firing arrangements are such that little or no smoke is made. When electricity is not obtained from a large central station, it means that each works is producing its own power, and probably smokily from coal. Electricity, however, is inherently uneconomical for heating purposes, though it is very convenient for certain processes requiring heat.

Although some advantages of large electricity generating stations have just been mentioned, it must not be implied that there is no case for smaller stations. On the contrary, a good case based on sound thermal—and therefore possibly business—principles, can be made for generating stations no larger than have been in use for the last twenty years, provided they are combined with hot water distribution systems to neighbouring laundries, hospitals, hotels, public baths and the like, and even to private houses. Scientifically, it sets one's teeth on edge to see the familiar huge cooling towers of a power station discharging heat into the air, or the circulating pumps of another station discharging vast quantities of warm water into a river or canal. We know that roughly 60 per cent. of the thermal value of coal when used in a steam-boiler-engine system is carried away in the circulating water. At the laundries, hospitals, baths, etc., just named, coal, gas and oil are used for warming water, and in many instances these institutions are close alongside a power station. In one such case I have in mind the swimming baths were shut because of the coal shortage, and nearby is a group of these cooling towers dissipating 60 per cent. of the heat value of the scarce coal into the air—surely corresponding actions on the part of a man in the street would lead to his retention in an asylum. In America (which, unfortunately, we allow to lead in now-a-days in so many matters) the use of the condenser heat has been used as the manner indicated for many years, and small indications of similar action can be found here : but we need to institute some heat-saving weeks, just as we already have Empire shopping weeks.

For heating purposes, the distribution of producer-gas (as is done by the South Staffordshire Mond Gas Co.) is more suitable than electricity. It would enable gas engines to be used for power if desired, and it could be used for domestic cooking and heating. When I first advocated this many years ago, it was objected that to have producer-gas laid on to a dwelling house would be dangerous on account of its composition. Now that ordinary town gas contains so much carbon monoxide, this objection can no longer be used specifically against producer-gas.

Another wicked waste of heat, and therefore coal, is taking place at gas works on account of the very high temperature at which flue gases are discharged from the retort furnaces. The obvious thing to do is to place an electric light works on top so to speak of the retort house of every large gas works. It is a pity that a certain natural antagonism between gas and electricity companies has so far probably prevented this

from being done. An enterprising financial group is needed to start a new company which shall supply both gas and electricity, then we should have an efficient combination and a great saving of coal.

In this connection, and especially as an American lead has just been mentioned, it is very pleasing to be able to refer to an exceedingly clever British invention, namely, the Still engine. It has been known in a quiet way for many years during which, with most commendable financial pluck (note the use of private enterprise and the capitalist), the directors of the Company have been finding the large sums of money necessary to carry out the difficult work of applying to practice the sound scientific principles underlying the invention. When the scientific principles of an invention are sound, it is only a matter of brains, time and money for the invention to be brought to a practical and commercial conclusion, but if the principles (or lack of them) of an invention are unsound, then no amount of money will make it a practical success, and yet for the lack of scientific advice one frequently sees money and effort wasted on something which is quite unsound in principle. The inventor of the Still engine was impressed by the fact that in an internal combustion engine (though giving the highest thermal efficiency so far) has an efficiency of only about 34 per cent., and that about 30 per cent. of the heat is wasted in the jacket-water for cooling the cylinder, while another 30 per cent. is wasted by the exhaust. He has therefore made a clever combination of a Diesel oil engine, a steam boiler and a steam engine. The subject is worthy of a much fuller treatment than can here be accorded, but, briefly, the principle of the engine is that part of the water-space of the boiler is formed of the jacket of the cylinder of the Diesel engine, and the temperature of this boiler water is uniformly 320°F. The piston of the engine is double acting, *i.e.*, on one side of it the cylinder is used as an oil-engine cylinder, having a two-stroke cycle, while, on the other, the cylinder is used as a steam-engine one, the steam being obtained from the boiler already mentioned. The exhaust from the oil engine end is passed among water tubes forming part of the steam boiler, and thereafter passes through a feed water heater for the boiler feed. Hence, we see the usual two great sources of loss are largely eliminated. The boiler is fitted with oil burners which are used only for starting-up purposes, or (in the case of marine engines) for manœuvring.

This engine is at long last (you will remember the Parson's steam turbine had a similar history and is now a great success) a practical success. One of the 2,500 s.h.p. is in the M.S. *Dolius*, of 11,500 tons displacement, belonging to the Holt Line, and she has made six return trips to Japan and elsewhere, totalling about 100,000 miles, on an oil consumption for *all* purposes of 8.67 tons per 24 hours, while on full load tests the oil consumption of her engines was 0.35 pounds per b.h.p. hour, giving a thermal efficiency calculated on the i.h.p. of 40.5 per cent. or on the b.h.p. of 37 per cent., which I believe, is a world's record. The mechanical efficiency at full load was the high one of 90.5 per cent.

A pair of stationary Still engines has recently been completed by Peter

Brotherhood, Ltd., to fulfil an order for the Hull Municipal Pumping Station. Each engine has a two-stroke cycle, a speed of 300 r.p.m., and gives 375 b.h.p.

The application of the Still engine to a main line locomotive is in an advanced stage at the works of Messrs. Kitson & Co., Leeds, the preliminary engine tests having been completed. The steam side of the Still engine overcomes the inherent difficulty connected with the application of an internal combustion engine to a locomotive, namely, that the latter cannot start against a load. The steam end also obviates the need of electric or other variable transmission gear between the engine and the driving wheels.

As a result of their experience of the M.S. *Dolius*, Messrs. Alfred Holt & Co. have placed an order with Scott's Shipbuilding Co., of Greenoch, for another M.S. with Still engines of 5,000 b.h.p. The average speed of the *Dolius* was 11.3 knots. The new vessel is to have a speed of 13½ to 14 knots.

There is much more I should like to describe, but though this paper is already twice as long as it should be, it is not half as long as necessary, merely to enumerate the principal features of modern power production. It may be useful to give a few references, *e.g.*, Mr. L. C. Harvey, the secretary of the newly-formed Institute of Fuel Technology, has kindly supplied me with a copy of his article on "Smokeless Cities," at p. 1053 of *The Municipal Journal* of December 7th, 1923 ; of "Smoke Abatement and City Smoke Ordinances" (1912), by Samuel B. Flagg, of the Bureau of Mines, U.S.A. ; and of "Smoke Abatement" (1923), by O. Monnett, also of the Bureau of Mines. Another paper is "The Formation and Prevention of Smoke," by C. F. Wade, at p. 451 of *The Electrical Times*, Vol. 69, No. 1799, April 8th, 1926. These give a mass of useful information.

In conclusion, let me say that I have referred to many aspects of our subject, and have probably omitted as many as named. This has not been done by malice aforethought, but from lack of knowledge and space. It is hoped, however, that these notes will serve their purpose, namely, the provocation of a good discussion.

DISCUSSION.

Dr. A. E. Smith (Hon. Secretary of the Fuel Section of the Society of Chemical Industry) said he was sure that many of those present would like to discuss Mr. Ackermann's full resumé of what was being done, and it was now open for discussion. There were some points he himself would like to make, though it was quite possible others might raise them. Mr. Ackermann had apparently held out hopes that gas and electricity works might combine for the utilisation of waste heat. He might not quite appreciate that in the first place it was only the moderate sized works and the larger ones where the quantity of waste heat was sufficient to justify the capital expenditure. If one deducted from the total number of gas works the number of small ones, it could be said that well over 50 per cent. of the waste heat in gas manufacture was now being

saved in heat boilers, steam being thus raised. If a gas works could use its own waste heat from the retort house it would not obtain enough steam for its own local purposes, after having absorbed the whole of the waste heat. There would be none to spare for electrical production. This raised the question as to whether steam should be raised for power production at the present time by the *Brunler* burner, as the produce of combustion must pass away without steam. The problem of combustion had not yet been overcome.

Bailie SMITH (Glasgow) said that they could congratulate Mr. Ackermann on his splendid condensation of a very large subject indeed. Those who had followed it could only pick out for comment one or two little bits in which they happened to be specially interested. There was a point (on page 6 of the paper) that should appeal to members of local authorities. It was that dealing with the waste which took place at gas works. That might apply to companies but certainly should not be applicable to local authorities, like that in Birmingham and other places, who owned both gas and electricity undertakings. About the year 1917 he happened to be a member of the Departmental Committee on electric supply and the gas industry of which the Chairman was Sir Archibald Williamson. It was reported to that committee by one of the greatest authorities on gas in Great Britain that the ideal in the future generation of electricity was a close co-operation between the electrical undertakings, but the ideal in the use of coal for the future was that the gas undertakings should carbonise the coal, take out the by-products and in every way make the most of it, and sell the gas to the electrical undertakings who would use it in internal combustion engines and to fire their boilers. That was stated in 1917, and he did not know to-day of a single gas undertaking that ever made a move in that direction. Rather, he thought, they had opposed any conjunction with the electricity undertakings. We had arrived at a critical time in the history of coal, and he suggested that those local authorities owning both undertakings should immediately take up that question of trying to get co-operation. It was all really owned by the citizens or townspeople, and it should be worked solely for their benefit. Glasgow had already started it. There were things to be got out of coal that would help, if necessary, to pay higher prices for it and yet give greater efficiency. In Glasgow, for instance, they found that they got 16 gallons of crude oil per ton from the coal. Co-operation was what was wanted.

Mr. E. KILBURN SCOTT (London) said that Mr. Ackermann did not mention the development of steam accumulation due to Dr. Ruth, which had been widely used in Scandinavia and Canada, and was now being introduced here. It represented one way of reducing the smoke nuisance because it had to be recognised that many Lancashire boilers were used for the purpose of boiling for dyeing and other classes of work. However good or conscientious a stoker might be he could not remedy the problem presented by boilers from which steam was gulped, for it was at such times that much black smoke was made. The best way to overcome the difficulty was to instal steam storage, and Dr. Ruth's system was an excellent way to do it.

There was a reference to the fact that the pulverised semi-coke which resulted

from the McEwan-Runge system could be stored without danger, and if pulverised fuel was ever used for ship work, that was the way in which it might well be done. The fuel could be pulverised at the ports and stored in the manner in which we now store oil, and it could be pumped into bunkers as readily as oil.

The problem of the "cathedral-like" combustion chambers hitherto necessitated for pulverised fuel firing, had been overcome by the boiler of the Steam Generator Co. Ltd., as installed at the Trafford Park Works of Taylor Bros. This boiler had no separate combustion chamber underneath, and with a heating surface of only about 2,000 square feet, the output of steam could be pressed to about 40 lb. of high pressure steam per square foot of heating surface per hour.

With regard to the development of sun power, he would like to ask Mr. Ackermann his opinion regarding the merits of reflectors and lenses for getting the sun's rays on to the boilers. The lenses would be made of curved sheets of glass with water flowing between, which, on becoming heated up, could be used as the boiler feed.

In tropical parts of the British Empire sun power was quite a feasible proposition and should be especially valuable as a means of pumping water for irrigation purposes.

In referring to the Wollaston gas-producing plant, Mr. Ackermann did not mention that a Wollaston producer and Cochran boiler working at the exhibition was giving 18 to 19 per cent. of Co2—a remarkable figure, when one considered that many of the boiler plants in this country gave less than 10 per cent. of Co2.

He had seen a mercury vapour boiler at the G.E.C. works in America and noted the great care that had been taken to make all the joints absolutely gas-tight. The turbine was over the boiler, and when the mercury was condensed it ran down into the boiler by its own weight, so a boiler feed pump was not required.

He wished to make a passing reference to the question very properly raised by Mr. Ackermann as to the future of smaller power plants, for it was, he thought, wrong to assume that the whole of the electric power of the country should be made in a few super-power stations. He believed in independent power plants for collieries and for large industrial works where steam was required for heating and process work.

Messrs. Cadbury Bros. Ltd., at Bournville, purchase about half the current from the corporation because they find it advantageous to make the rest with their own power plant, the reason being that they used steam from the engines at 25 lb. per square inch for heating the buildings and for boiling purposes, etc.

Some of the smaller power stations situated in centres of cities which were to go out of operation for electric supply might well have the boilers turned over to steam heating purposes. This has been successfully done in Pittsburg and other cities of the U.S.A., where it is customary for the churches, theatres and hotels to be supplied with heat in this way. In hotels and restaurants it was used for cooking purposes.

Mr. Roberts (Manchester) said he was very much interested in the question of pulverised fuel. He was against its use for the reason that some of the works in Lanca-

shire threw up a great amount of grit. It was all very well to gloss over and make light of the fact that some bacon in a shop near a factory using this fuel had to be covered up because of the grit, but when tons of it were thrown over a district, it was not fair to the inhabitants living near to the factory. They had some managements who were careful to emit the grit in small quantities at a time, but he knew of one which emitted tons of it at a time when the wind was in a certain direction. He failed to understand why the pulverised fuel was being used when, he understood, members of the League and a number of experts, after visiting the Barton Super Electrical Works, found that coke was cheaper and produced steam very cheaply and without grit at all. In this case it had been found that it was cheaper and more economical than the pulverised fuel. They had heard from at least one speaker that boilers had given very satisfactory results with coke alone. He hoped that the day was far distant when they would see the pulverised fuel being carried through the streets of Liverpool and Manchester for use on steamships.

Mr. E. W. L. Nicol said that in London important work had been done by the London Coke Committee in promoting the use of coke for power purposes. Very close co-operation had long been established between gas works and electric power stations Three London power stations had between them consumed upwards of 100,000 tons of coke a year. They use coke not altogether because of its smokeless characteristic, but because they had found from experience that it gave, economically, the best results. In Birmingham and in Manchester also, coke was now being used very largely at the power stations. In Birmingham, at the new Prince's Power Station, they were using, he believed, something like 600 tons a week, or, about 11 per cent. of the total fuel consumption—a considerable amount. At the Barton (Manchester) plant they had used as much as 50 per cent. coke, and the thermal efficiency and output results compared very favourably with those obtained when pulverised coal was used, and this without the emission of excessive dust. The question of the dust emission from pulverised fuel plant was one that could not be ignored, but the use of coke as fuel at electric and other stations would tend materially to prevent the formation and emission of smoke in industrial areas.

Mr. E. C. Mills (Manchester) stated that for many years he had given close attention to the question of the direct production of power from our best source of heat, viz., coal. His conviction was that the wisest course to adopt was to take as short a cut as possible from the origin of heat, as existing in the coal, to the product, in this case, steam. The Wollaston principle gave, in his opinion, excellent results, scientifically and economically. All the constituents of coal were burned primarily for the production of gas. His only criticism was that, up to the present, at any rate, it was not applied to large horizontal boilers.

In 1913 he (Mr. Mills) built a gas producer for this purpose, which gave very satisfactory and smokeless results, but owing to the war operations were stopped, and financial difficulties which had arisen since had prevented any further development. It was not more costly than a pulverising plant, and did away with the necessity of an

economiser. He applied this gas producer right in front of a Lancashire boiler. Every constituent from which gas could be made was gassified, and all the non-combustible matter was taken out in the producer, and did not enter the boiler. He thought this cut out, so far as steam raising was concerned, all such processes as pulverised fuel and low temperature carbonisation.

In referring to other sources of power, Mr. Ackermann had not included oil, as used in internal combustion engines. He (Mr. Mills) had had occasion recently to go into the question of costs of various methods of driving, and the results were as follows, taking 100 as representing the result with oil engines :—

	Relative Cost.
Oil engine, direct drive	100
Electricity, produced at home by oil engine	107.5
Steam by coal	134
Steam by oil fuel (best system)	186.5
Electricity from outside	300

Councillor J. H. Newsome, J.P. (Harrogate), gave an account of the experience of Harrogate in an attempt to use oil fuel and supply hot water to the baths, hotels and other public institutions. They spent about £17,000 in the purchase of two Diessel engines and equipment, but had to scrap the whole scheme, because, they found, firstly, that the use of the water would not justify the expense they would have been put to in supplying it. Secondly, a great quantity of smoke came from it. Thirdly, the cost of running was too high, and it paid them better to go back to coal which they got at less than 30/- per ton and produced electricity very economically. The experiment was a very costly one.

Mr. Neville (Birmingham), touching on the bonus system for stokers as an inducement to smoke abatement, asked if Mr. Ackermann could tell them of any scheme or apparatus for recording when smoke was being produced. Any smoke bonus scheme should include a payment for no smoke, with deductions when black smoke is emitted from boiler stacks ; such a scheme cannot be operated fairly, however, when it relies on casual observation. Black smoke made at night is not seen, and he would like to get hold of an apparatus for recording smoke. There are indicators on the market, but he had never heard of a suitable recorder. Had Mr. Ackermann any knowledge of a commercial instrument that would give a record of smoke produced from chimneys ?

Mr. Ackermann, replying, said that with regard to the Chairman's remarks and those of others, about placing the electricity works on top of the gas works, he had the misfortune or good fortune of living in London, and recently he paid a visit to one of the very big gas works. They had no waste heat boilers of any kind, and yet they developed an enormous temperature. It was heart rending to see such a waste of heat. He quite saw the point that some of the smaller gas works should make use of their own waste heat. The pity was that in so many cases there should be such a scandalous waste of heat. He was very glad to hear that some of the smaller plants were making

use of their superfluous heat. The Brunler boiler was their great trouble. As a heat producer for hot water and things of that sort it might be all right—though you could not drink the water. They must not, however, be too critical. If one compared the first motor cars with the modern Rolls-Royce it was very laughable.

Mr. Kilburn Scott had made a number of interesting additions to the information in the paper. With regard to his question about lenses and reflectors in the use of sun power, he (the speaker) did not feel very hopeful about lenses because of the immense size they would have to be made. A lens 25 feet in diameter would be a very large one, and the erecting of sufficient units of solar energy would be a costly undertaking. The plant in Egypt, to which he had referred, had five rows of reflectors, 200 feet long and 13 feet 6 inches across each of the five units. These could be made almost any width or length, and of planished steel or polished tin. Even all that only gave 65 b.h.p. When you came to lenses you had to remember that to cover an acre of land with lenses was going to prove a most expensive apparatus, and every lens would have to be orientated to the sun.

He was pleased to learn Mr. Kilburn Scott's opinion of the use of sun power for irrigation work, as he felt that ultimately solar energy was bound to be utilised. He had no information about the large water filled lenses. They would be costly, liable to be broken ; would have to be oriented to keep them normal to the sun's rays, and would probably be the means of supplying only about 5 h.p. each ; so that for an irrigation pump many would be necessary, and the orienting gear would then become distinctly complicated.

Regarding Mr. Kilburn Scott's other useful contribution to the discussion, he reminded the meeting that at the end of his paper he said many aspects of the subject had probably been omitted due to lack of knowledge or space ; hence, the omission of any reference to Dr. Ruth's system of storing steam, which appeared to be similar in effect to Druitt Halpen's thermal storage, which was mentioned in the paper.

With regard to one speaker's objections to the grit on the bacon in a grocer's shop, which the speaker concerned put down to the use of pulverised fuel, as a matter of fact, in the case in point, the grit did not emanate from pulverised fuel, but from a steam furnace operated by crude gas. In any case, in his opinion, that little bit of black powder that was coming over on to the grocer's goods was very much less objectionable than soot and tar. The grocer was able to keep the grit off with a piece of paper. This he could not have done with soot or tar. There was an apparatus for collecting the dust from flue gases, and doing the job very efficiently, too. In this particular case, if he had known of that apparatus at the time, he would have recommended that it should be fitted to the chimneys of the firm in question. That was not the only trouble. The objection was more a question of noise than grit. Personally, if he had had to have either grit (highly calcined grit, that was) or soot and tar coming over from a furnace, he would say, let us have the grit. That, at least, will dust off.

He had not mentioned oil fuel, as it was now so well-known for use in oil engines and for firing boilers. The experiment at Harrogate, mentioned by Mr. Newsome, had proved very disappointing, but one could not expect success every time, or the first time. He should be sorry to condemn the oil system simply because they had had bad luck at Harrogate. Perhaps the power station was not central and the distances to the hotels, etc., were too great. One would like to know lots more about this particular experiment before condemning it generally on the failure of the Harrogate plant. As an instance of the truth that one must not expect perfection in the early stages of anything, he could recall, in the early days of the London motor 'buses. It was a common sight in a morning to see numbers of the 'buses lined along the route to the city after having broken down, while the drivers of the horse 'buses would shout : "All the way to the Bank without a breakdown." Now, it was a most exceptional thing to see a motor 'bus laid up.

Mr. Neville had asked if he knew of any recording apparatus which would measure smoke at night time, or, in fact, at any time. The nearest thing he knew was Dr. Owen's apparatus. He saw no reason why this should not be applied to smoke. He himself had used it in connection with an experiment at Bletchley. On that occasion he got into the smoke as much as possible so as to record it with the instrument and compare it with the normal air. He did not see why it should not be applied to the tops of chimneys, or to flues, although he did not know of any case where one of these instruments was in regular use. They had not even an apparatus for scientifically recording the thickness of black smoke. The human factor always came in there, though with Dr. Owen's instrument, it did not. They had to gauge the apparent density of the smoke by its depth of colour. But, by taking a reading of flue gases from heavy black smoke, it would be possible to see the deposit, and that would eliminate the human factor.

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